American Journal of Agricultural Economics

Volume 61 Number 1

February 1979

21

In this issue: Proceedings from the 1978 fall meeting

AAEA Annual Meeting
Washington State University
Pullman, Washington
29 July–1 August 1979

The *American Journal of Agricultural Economics* is published five times a year (February, May, August, November, December) by the American Agricultural Economics Association. Prior to 1968, this *Journal* was the *Journal of Farm Economics.*

Printed for the AAEA by Heffernan Press, Inc., Worcester, Massachusetts, USA.

Second class postage paid at Lexington, Kentucky, and additional mailing offices, Pub. No. 019500.

Editorial Policy

The purpose of the *Journal* is to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscripts should have a relationship to the economics of agriculture, natural resources, or rural and community development. Contributions, methodological or applied, in the business, extension, research, and teaching phases of agricultural economics are equally encouraged.

Editorial Communications

All manuscripts and editorial correspondence, except as noted below, should be addressed to the editor, V. James Rhodes, Department of Agricultural Economics, Mumford Hall, University of Missouri Columbia, MO 65211

Communications concerning book reviews and books submitted for announcement in the *Journal* should be sent to the book review editor, Herbert H. Stoevener, Department of Agricultural Economics, Oregon State University, Corvallis OR 97331.

American Journal of Agricultural Economics

Volume 61 Number 1
February 1979

Articles

Notes

Proceedings

Articles

Artistic Research Tools for Scientific Minds

George W. Ladd

The topics of this paper are frequently-used, versatile research tools: subconscious mental processes (imagination and intuition), chance (including serendipity) and writing. Conditions that may stimulate subconscious mental processes to generate useful ideas are discussed. They are doubt, venturesome attitude, diversity, thorough preparation, tension, temporary abandonment, relaxation, writing, exchange with colleagues, freedom from distraction, and deadlines. Various forms of chance and their roles in research and problem solving are discussed. It is argued that writing is not only a research-reporting tool but is also valuable in performing research.

Key words: chance, imagination, intuition, serendipity, writing.

Two criteria that we teachers apply in selecting topics that we want students to learn are (*a*) frequency of application and (*b*) versatility. But, in violation of our own criteria, we pay little attention in our courses to the research tools that are the most versatile and frequently used of all.

The topics of this paper are some frequently-used, versatile tools: subconscious mental processes (imagination, intuition, hunch), chance (including serendipity), and writing. These topics receive little attention in our courses.

On the criteria of frequency of use, consider. In the twenty-three years that I have been doing economic research, I have made six different applications of linear programming. Some applications took a few weeks. Others lasted about a year. If we allow one year per application—a generous figure—we find that in sixteen of the twenty-three years, I have not been using linear programming. But I use subconscious mental processes daily, and write at least weekly, and take advantage of chance whenever I can, which has been more than six times. A similar condition prevails for others with whom I have talked. They use subconscious mental processes and writing more frequently than they use quantitative tools that they were taught as students, and their careers are affected by luck.

On the criteria of versatility, consider. Linear programming is one of the most versatile tools available to economists. But there are a number of problems for which it is inappropriate. Linear programming has not proved useful for estimating consumer demand functions or for solving truck routing problems. Neither is it useful for obtaining the data needed for a linear program. Each research tool we teach students is, like linear programming, inappropriate for many problems. But subconscious mental processes, writing, and chance are useful for any problem, at every stage of every research project.

Application of the criteria of frequency of use and versatility lead me to conclude that students need to be exposed to the topics of this paper. This paper is addressed mainly to students. But even an experienced investigator who knows the importance of the tools discussed here may find a systematic discussion to be helpful.

Evidence on the usefulness of these tools can be found in books of Austen (a neurologist), Beveridge (an animal pathologist), Hadamard and Polya (mathematicians), Young (a biologist), and Porterfield (a sociologist), and in writings cited in these books. Wiener's (p. 72) first stage in the inductive research process is "the imagination of a theory to fit the facts." Even philosophers of science acknowledge the importance of subconscious mental processes in research. See for example Braithwaite (p. 27) and Popper

---

George W. Ladd is a professor of economics at Iowa State University.

Earlier versions of this paper were presented at an Iowa State University Economics Department seminar and at a Computer Science Department colloquim. The present paper has benefited from the discussions at those sessions and from suggestions of Bob Holdren, John Miranowski, Wayne Ostendorf, and Ronald Raikes.

(pp. 31, 32). Hicks' reaction to Keynes' *General Theory* is appropriate here. Hicks wrote:

> I must confess that, as I have worked with Mr. Keynes's book, I have been amazed at the way he manages, without the use of any special apparatus, to cut through the tangle of difficulties that beset him, and to go straight for the really important things. He succeeds in doing so just because he makes free use of his superb intuition and acute observation of the real world, in order to be able to discard the inessentials and go straight for the essentials. (p. 4)

Intuition is subconscious. Observation involves the conscious and the subconscious.

The purpose of this paper is to present ways of making subconscious mental processes, chance, and writing more productive.

Subconscious Mental Processes

Have you ever had an experience like this? You are talking and making a point that requires you to talk for two minutes. Halfway through the two minutes you become conscious of a useful idea, but by the time you complete the two minutes of talk you have lost the idea. And you are unable to remember or recreate the idea. Your subconscious mental processes created a suggestion and put it forward for your conscious mind to catch, and your conscious failed to catch and hold the idea.

In the "Born Loser" comic strip of 6 October 1977, Mr. Born Loser is walking along mumbling to himself, "Backward, turn backward, Oh time in thy flight, I just thought of a comeback I needed last night." Perhaps this has happened to you. An hour after an argument, a good idea occurs to you that would have won your case.

These experiences are typical of subconscious processes. The term "subconscious" describes mental processes such as thoughts, ideas, and feelings that occur in our mind without our being conscious of them. Freud's comparison of the human mind to an iceberg illustrates the view held by many psychologists of the subconscious (or unconscious as they call it). Only one-eighth of the mass of an iceberg is above the water; the remaining seven-eighths is below the surface of the water. Only a small fraction of our mental processes are conscious—above the surface of consciousness. A large fraction of our mental processes are below the surface: subconscious (or unconscious) processes.

Normally, we are not aware that our subconscious is operating because the thoughts it throws up to our conscious combine with our conscious thoughts to provide an orderly, reasonable, ordinary stream of consciousness. It is only when the subconscious puts up a new, exciting, extraordinary thought that we are made aware of its operation, or when it puts up a thought on a topic other than the one we are consciously pondering.

Many of our concepts and thoughts originate in the subconscious. Conscious reason is used to examine and accept or reject the proposal from the subconscious.

Given Freud's comparison of the mind to an iceberg and given that ideas originate in the subconscious, it is desirable to increase the productivity of the subconscious. This can be done because the subconscious does respond to stimuli. And a person can exercise some control over the amount, variety, and strength of the stimuli his subconscious receives. By controlling these stimuli, he exercises some control over his subconscious.

It is not enough, however, to stimulate one's subconscious. One must also sensitize one's conscious mind to the operations of the subconscious in order to minimize the number of ideas from the subconscious that are lost before they penetrate the conscious. Some of the things a person does to stimulate his subconscious to create ideas, also stimulate his conscious to grasp the ideas.

Most of the ideas generated by our subconscious processes turn out, upon evaluation by our conscious mental processes, to be useless, or at least useless in the context in which they came to mind. This means that, because the subconscious is often wrong, the person who desires to increase its usefulness must have more ideas, knowing that a large proportion of them will be bad ideas. And he must use his conscious mind to discriminate.

Imagination and Intuition

Psychologists speak of several kinds of imagination. Daydreams and nightdreams are instances of passive imagination. Reproductive imagination is the capacity to form mental pictures of past experiences. The kind of imagination of most concern in science is productive or creative imagination. Senator Robert F. Kennedy is reported to have said, "Some people see things as they are and wonder why. I see things that never were and ask why

not?" To "see things that never were" is an act of creative imagination. The product of creative imagination is a new invention. The new invention may be something physical like the wheel. It may be an artistic piece. It may be a new concept or new idea or new model, (e.g., autoregressive least squares). Frequently the product of the imagination is a link between things that were not formerly seen to be connected in any way. "A thing learned in certain connections is torn out of the context in which it was learned, for use in some new context" (Guilford, p. 100). Ideas, facts, relationships, or concepts become dissociated from their previous contacts and become associated together in new ways.

Porterfield discusses synopsis and synthesis as processes of imagination. Synopsis or "whole-sight" provides a view of the whole of a problem or situation. Synthesis provides understanding of relations among the parts of the whole. Hadamard (p. 23) argues: "The unconscious has the important property of being manifold; several and probably many things can and do occur in it simultaneously. This contrasts with the conscious ego which is unique." Because of the uniqueness of the conscious and the manifold character of the subconscious, the act of synthesis is performed in the subconscious rather than in the conscious. In discussing creative imagination, Weld writes:

> Without warning but usually after long incubation and as the result of some chance situation, or some grouping of associative tendencies, a new meaning, a happy thought, is born. . . . In view of the suddenness of its initiation, its unaccountableness, its feeling of strangeness and the joy which it sometimes brings, the new idea often seems to come as an inspiration from on high. Sometimes the new conception comes in its complete form. . . . But at other times and more frequently, the new idea is vague, incomplete or only in outline. . . . (p. 707)

The terms suddenness, unaccountableness, strangeness, joy, inspiration are terms sometimes used to describe intuition. In philosophy, intuition is defined as immediate knowledge attained without conscious deliberation or reasoning. In the theory of knowledge, intuition is the immediate apprehension of truth. It is "knowing without knowing why I know." Beveridge (p. 91) defines it as "a sudden enlightenment or comprehension of a situation, a clarifying idea which springs into the consciousness, often, though not necessarily, when one is not consciously thinking of the subject. . . . Ideas coming dramatically when one is not consciously thinking of the subject are the most striking examples of intuition, but those arriving suddenly when the problem is being consciously pondered are also intuitions."

We all have these intuitions. Subconscious mental processes are research tools, just as is linear programming, and the subconscious mental processes that create intuitions can be stimulated to be more productive.

Four Stages of Invention

Wallas has described the inventive process as consisting of four stages: preparation, incubation, illumination, and verification.

Preparation is a conscious, voluntary, willful effort that is required to stimulate the subconscious. The rules for the preparation stage include "the whole traditional art of logic, the mathematical forms of which are the logic of the modern experimental sciences, and the methods of systematic and continuous examination of present or recorded phenomena . . . and the voluntary choice of a 'problem-attitude.' Our mind is not likely to give us a clear answer to any particular problem unless we set it a clear question . . ." (Wallas, p. 84).

The incubation stage is a stage of subconscious mental activity. "During incubation we do not voluntarily or consciously think on a particular problem and . . . a series of unconscious and involuntary . . . mental activities take place" (Wallas, p. 86). Illumination is the same as Beveridge's "sudden enlightenment or comprehension."

Wallas discusses verification as a conscious, voluntary, willful effort. It is guided by the same rules as preparation. One purpose of verification is to test the illumination against logic or mathematical rules, experience, and other knowledge. Another purpose is to express the results in language. A third purpose is to "precise" the results, that is, to state the results completely and precisely. A fourth purpose is to prepare for using the illumination. What Wallas calls verification, some people would call verification and validation.

Typically a person is simultaneously engaged in two or more of these stages on two or more problems. Conscious verification of an answer to one problem is preparing him for subconscious effort on a second problem while his subconscious is incubating on a third

problem. Work on any single problem does not follow these steps in strict sequence. Rather, investigators jump back and forth from one step to another.

Conditions Stimulating to Subconscious Mental Processes

Reading, discussions, and introspection lead to the belief that many people's subconscious minds respond to the stimuli discussed here.

Doubt

In those instances when you are most doubtful of accepted modes of thought or of conventional questions or approaches, your subconscious is more apt to generate novel ideas than when you are satisfied with the conventional wisdom.

Venturesome Attitude

You are not going to break ground by developing something new if you are paralyzed by the fear of making a mistake. Don't be afraid to make mistakes. There are plenty of people around who will delight in pointing out your errors. Think how much pleasure you will afford those people if you do make a mistake! I think it was John Maynard Keynes who astutely observed, "It is not so terrible to make a mistake. What is terrible is not to be found out." By the time each of us finishes formal schooling, he has been caught in enough mistakes that he knows that being found out does not destroy one's ego or self-esteem. Being caught in a mistake after leaving school is not more destructive of one's self-esteem than being caught in a mistake while in school.

Probably fear of failure also inhibits us. But, if a failure now and then is going to ruin your career or your self-esteem, your successes must not be worth much. Perhaps this suggests a career that is a mixture of some "safe" projects and some "risky" projects so that successes on the "safe" projects can compensate for possible failures on the "risky" projects. But failure is unpredictable. On some projects you will fail to achieve what you initially thought were modest objectives. In some cases you will achieve objectives that you initially had no idea how to achieve.

One reason for this may be some sort of compensatory principle. A greater curiosity about or interest or challenge in the risky project elicits more preparation and effort. Too, a magnificent failure can be more exciting than a modest success.

Few things in life are more gratifying than accomplishing a task that you once believed to be impossible. It is appropriate to recall that Pogo (in Walt Kelly's comic strip of the same name) once observed, "We are confronted with insurmountable opportunities."

Diverse Experiences, Memories, and Interests

One condition favorable to a fruitful subconscious is diversity of memories, experiences, and interests. A fruitful intuition is often the perception of a connection between things that were previously unconnected. A varied store of memories and experiences makes it possible for your subconscious to perceive connections between things that you would not even be aware of if your experiences were less varied. One of the advantages an experienced investigator has over a young researcher is that the former has a more varied store of memories and experiences to draw on.

From his studies of problem solving, the psychologist Raaheim has concluded, "The more experienced you are, the more problems you are likely to be faced with. And . . . the more problems you are likely to solve" (p. 87).

The diversity need not all be in professional interests and experiences. Austen emphasizes that research results are the accomplishments of the whole person, not just of a compartmentalized "professional" portion of a person, and presents examples to show that his hobbies of music, watercolor painting, and hunting have contributed to his research in neurology. A person can acquire diverse experiences vicariously by reading on a variety of topics. Mighell argued that economists should read widely.

Variety in experience does not come simply from living. You must make an effort to obtain it. A young assistant professor had failed to make this conscious effort. He had been at one school for three years when he learned that a desirable position was open at another university. He quickly applied for the position. In his application, he emphasized the benefit of his three years of experience. His department head, however, saw it differently. In his letter of reference he wrote, "This young man claims to have had three years of experience.

This is not so. He has had one year of experience three times."

Thorough Preparation

Preparation precedes subconscious mental activity. The more thoroughly your conscious mind has grasped the problem—in general outline and in detail—the better is the chance that your subconscious will produce fruitful ideas. Subconscious processes are stimulated by vigorous conscious processes.

How does one go about preparing thoroughly? Some relevant considerations were presented under the section, "Four Stages of Invention." Careful formulation of the problem is an important part of preparation.

Tension

Conscious absorption of a problem, teamed with an intense desire to know, provides a strong stimulus to your subconscious. In discussing the creative person, Maslow (p. 47) has written of "this total fascination with the matter-in-hand, this getting lost in the present, this detachment from time and place." Such total immersion in a problem bespeaks of intense concentration and overpowering desire for a solution. The stereotype of the absent-minded professor has a factual basis in the actual behavior of professors experiencing "this detachment from time and place" while in the throes of "tense thought," to use Hadamard's term.

What are sources of a strong desire for a solution? One is certainly curiosity. It seems to me that curiosity has an aesthetic component: an intellectual aesthetic sense, or a yearning for intellectual tidiness. Beveridge (p. 77) wrote of the "love of order and logical connection between facts." Polya (p. 45) expressed it, "The feeling that harmonious simple order cannot be deceitful guides the discoverer both in the mathematical and in the other sciences." An aesthetic tension is created by an incomplete or broken pattern of facts and ideas or a pattern with discordant pieces. This tension is discomforting. When you finally see the pattern complete and unbroken, you experience a delightful release of the tension. You perceive something soothing or delightful to your sense of intellectual aesthetics. Curiosity may also have a component of the naive, open-eyed wonder of a child at the marvels of the world. Another source of strong desire for a solution may be your ego. Obtaining a solution gives you a sense of mastery. Your desire for a solution may rise from a feeling of frustration: frustration with the inadequacies of present answers to a question, or irritation over the lack of an answer.

Temporary Abandonment

A practice that most people find favorable to subconscious activity is temporary conscious abandonment of the problem. Upon returning to the problem later, one frequently finds that he has acquired new ideas or insights in the interim. One undesirable result of over-long conscious pondering of a problem is conditioned thinking. Conditioned thinking is like cycling in solving a degenerate linear program: the mind continually retraces the same established (and fruitless) patterns of thought. Temporary abandonment helps to break these fruitless patterns. The value of temporary abandonment is reflected in the old proverb, "Sleep on it."

The essence of Wallas' second stage in inventive thought—incubation—is temporary conscious abandonment. You may also temporarily abandon a problem during the preparation stage. You may alternate between conscious thought and temporary abandonment several times before finally coming up with a solution.

One student working on his dissertation told me that when he was having difficulty, he would concentrate on the problem for the last fifteen to thirty minutes of his evening's work before going home, and then not think about the problem any more that evening. The problem frequently would be clarified, and sometimes solved, by the time he returned to his office the next morning.

A colleague has told me that he works most effectively when engaged in intense concentration if he takes a five-minute break every half-hour. During that five minutes he may take a coffee-break or walk to the water fountain for a drink. After the five-minute break, he returns to work refreshed.

You may temporarily abandon conscious efforts on one problem in order to turn your conscious mind to other problems. But you may also temporarily abandon conscious efforts on all research.

Relaxation

Some people find a period of relaxation or light effort—driving, shaving, walking—immediately following a period of serious effort to be a favorable time for intuitions. The subconscious processes of some people are active at night, and these people will be awakened during the night by bright ideas, or ideas will spring to mind just after waking in the morning. Some people find lying in bed in the morning while half-awake to be favorable to the appearance of intuitions. Some people find a combination of mental relaxation and physical exercise to be conducive to the appearance of intuitions.

Writing

Young expressed the attitude of many people toward writing when he wrote, "The scientist does not usually think of the writing of books or preparing of lectures as research. Writing seems to him to be a rather tiresome labour that he must do after the fun of laboratory research is over" (p. 1). But, later in the same paragraph that contained this statement, Young wrote "I came to realize the extent to which having to describe the results of one's thoughts to others is a part of the process of discovery itself."

Many of my intuitions come to me when I am writing. It frequently happens that "I don't know what I think until I write it." It sometimes happens, for example, that I start to write a paragraph knowing only the first sentence and having only a vague idea of the central theme. But by the time I reach the end of the paragraph I will have expressed some ideas that I did not have when I started the paragraph, or at least did not know I had.

Clardy beautifully expresses my attitude toward writing. She says, "I have acquired many things by writing them. There are allegedly those who know what they have to say before saying it, but I have never counted myself in their number. Argument seems to me a means of developing rather than merely demonstrating theories, and articulation a means of amassing rather than just disseminating insight. Writing is as much the cause as the result of having something to say."

The process of learning from your own writing does not end at the first draft. In discussing rewriting and restating the evidence, Penfield (p. 106) states, "often, once I get my thoughts truly expressed, I see things I never suspected before."

Precising the results and preparation for using the illumination are two purposes of the verification stage of invention. Precising the results involves stating them completely and precisely writing them. The writing helps you to prepare to use the results.

We usually think of writing as something that one does to report to others. What is being advocated here is writing to yourself to generate or discover knowledge. This position is similar to the one you have probably heard (and may have expressed yourself): "The best way to learn something is to have to teach it." For some statistical support for this view, see Siegfried. He concluded that proctoring an introductory economics course significantly improves the student-proctor's understanding of economics principles.

Exchange with Colleagues

Discussion with others can be helpful in various ways. Your colleagues' or students' comments can bring out points you had missed. They may bring a new perspective that provides you with new insight. They may point out an incorrect assumption you were making, and show you a correct alternative. They may complete a partial idea of yours.

Discussion has other values. Keynes wrote (p. vii): "It is astonishing what foolish things one can temporarily believe if one thinks too long alone. . . ." Discussion with colleagues provides a useful defense against believing foolish things. Take care, however, lest your colleagues teach you foolish things that you did not know before.

Some people find the most stimulating exchange with colleagues to be the exchange that occurs in a "pressurized environment," as when presenting and defending a paper before a friendly but critical audience. These people commonly say "I think better on my feet."

The difference between "writing" and "exchange with colleagues" is that writing represents an exchange with one's self.

Freedom from Distraction

Another condition favorable to the subconscious is freedom from distraction: interruption by others, intrusive noises, pressures to be working on several other jobs in addition to the one currently occupying you. Intrusive

influences that distract your conscious mind inhibit the operation of your subconscious mind. These influences also make it more likely that ideas generated by your subconscious will be overlooked by your conscious.

It is a common experience that putting in eight hours on research in two four-hour stretches is more productive than eight one-hour stretches. The reason may be that changing tasks requires redirecting your subconscious. Changing from one task to another shortly after the first task is initiated requires your subconscious to be redirected before it has time to accomplish anything on the original task.

In addition, frequent changing of tasks makes it difficult for your subconscious mind to absorb thoroughly any single problem. You might say that prolonged concentration on one problem permits the conscious to transmit information to the subconscious. When you change tasks frequently, the messages transmitted from your conscious are received by your subconscious as random noise.

Both temporary abandonment and distraction mean changing the course of your conscious thoughts. One is voluntary and the other is involuntary. If you do it to yourself, it is temporary abandonment. If I do it to you, it is distraction.

Deadlines

Some scientists do their best work when facing deadlines imposed from outside. For deadlines to have this effect, you must be able to work without distraction. It is questionable whether self-imposed deadlines do stimulate the subconscious. Such deadlines so easily can be set back by a few days or a few weeks.

The conditions most stimulating of all to your subconscious are those that combine a number of the individual conditions presented here, e.g., interdisciplinary brainstorming sessions in preparation for writing a report due the fifteenth of next month. This involves diversity, exchange with colleagues, and pressure of meeting a deadline.

Capturing Intuitions

It does you no good to have a fertile subconscious if your conscious fails to grasp the results of your subconscious processes. Intuitions frequently appear on the edge of your conscious and willful effort is required to grasp them before they are lost. You need to be alert to grasp these intuitions as soon as they appear. Commonly an intuition lost once is lost permanently. Some people wisely make a habit of jotting down notes as soon as an intuition appears.

Chance

Beveridge has written, "New knowledge very often has its origin in some quite unexpected observation or chance occurrence arising during an investigation. The importance of this factor [chance] in discovery should be fully appreciated and research workers ought deliberately to exploit it" (p. 55). And the mathematician Polya writes: "The first rule of discovery is to have brains and good luck" (p. 172).

Nelson (p. 256) reports:

> After he discovered the tuberculosis bacillus [Pasteur] was very often given evidence of the acute jealousy of people in his or in related fields. At a big reception at which Pasteur was the guest of honor one of his colleagues came up and said, "Isn't it extraordinary these days how many scientific achievements of our century are arrived at by accident?" Pasteur said, "Yes, it really is remarkable when you think about it, and furthermore, did you ever observe to whom the accidents happen?

Pasteur's response becomes more meaningful if you know that Pasteur believed that "Chance favors only the prepared mind."

Four Forms of Chance

Austen finds four kinds of chance that play roles in creative research. Chance I represents blind luck, completely accidental. In Chance II, good luck is the result of general exploratory behavior. Its major premise is that "*un*-luck runs out if you persist" (p. 73). Its main feature is general exploratory actions in promising directions. In Chance III, good luck is the result of personal sagacity. It occurs to the "prepared mind" when "some special receptivity born from past experience permits you to discern a new fact or to perceive ideas in a new relationship" (p. 78). Austen classifies Chance I, II, and III as serendipity, "the facility for encountering unexpected good luck as the result of accident, sagacity or general exploratory behavior" (p. 71). Chance IV "is the kind of luck that develops during a probing action that has a distinctive personal flavor"

(p. 75). Chance II involves generalized motor activity. Chance III involves one's personal sensory receptivity. Chance IV involves personalized motor behavior (action) that is focused in a specific manner that results from the investigator's own unique combination of skills, interests, background, aptitudes, personality, values, beliefs: from the person the investigator is. Austen's classification can make you aware of the different ways that chance can benefit your research and can thereby increase the likelihood that you will recognize those situations when you can be the beneficiary of chance.

The results of chance are not all beneficial in research; results of chance can also be harmful. The existence of "Murphy's Laws," their correlatives and variations are evidence of the awareness of the negative effects of chance. Austen (pp. 95–96) presents twenty such laws. The simplest version of Murphy's Law is, "If anything *can* go wrong, it will."

You do have some control over your luck. You cannot determine, but you can influence, your luck. Possession of a lively curiosity, active imagination, acute perception, diverse experiences, a retentive memory, and persistence will do a great deal to improve your luck.

One Solution Solves Several Problems

In one sort of serendipity, a method used to solve one problem turns out to be appropriate for solving a second problem that was not previously perceived as having any relation to the first; or a solution to one problem turns out to be a solution to an apparently unrelated problem. This justifies Polya's advice (p. 65): "Having made some discovery, however modest, . . . we should not miss the possibilities opened up by the new result, we should try to use again the procedure used. Exploit your success! *Can you use the result, or the method, for some other problem?*"

Polya's suggestion would worry some economists. These people are concerned that "too many agricultural economists are tool-oriented rather than problem-oriented. They learn a method or tool and then search around for problems to try it on." I think Polya's proposal is justified, and their concern is justified. These economists are concerned, I believe, about people practicing cookbookery or mathematistry, in Box's terms. The symptoms of cookbookery are "a tendency to force all problems into the molds of one or two routine techniques, insufficient thought being given to the real objectives of the investigation or to the relevance of the assumptions of the imposed methods" (p. 797). "Mathematistry is characterized by development of theory for theory's sake, which since it seldom touches down with practice, has a tendency to redefine the problem rather than solve it" (p. 797). It is possible to follow Polya's advice without engaging in cookbookery or mathematistry.

Hadamard (p. 50) lamented his missed opportunities when he "happened to overlook results which ought to have struck me blind." Following Polya's advice will reduce the frequency with which you miss opportunities to use your discoveries.

Problem Solving

It will give us greater insight into the various forms of chance if we consider some findings of psychologists on problem-solving behavior. Raaheim differentiates among three kinds of tasks. He first conceives of a series of earlier situations of the same sort. A problem situation is "the deviant member of a series of earlier situations of the same sort" (p. 22). The definition focuses at once on the elements that are common to the problem situation and the earlier situations, and the difference between the problem situation and the earlier situations. This definition treats as problems those "tasks which may eventually be solved by *intelligently* utilizing one's past experience" (p. 50), because intelligent behavior depends on an ability to reformulate one's past experience to meet the requirements of the present.

A second kind of task is a routine task. A routine task has no detectable difference from previous situations of the same sort. Solution of such tasks does not require application of intelligence, but use of memory.

The third kind of task is a novel task in which "the deviation from what are the familiar features is too great . . . when a familiar pattern is no longer recognizable" (Raaheim, p. 83). Intelligence is not a factor in solving such totally unfamiliar tasks. Application of intelligence to solution of such tasks can delay or even prevent finding a solution. "For the effective handling of very unfamiliar tasks, an exploratory activity is more rewarding than intelligent reflection" (Raaheim, p. 84). In experimental studies of people faced with novel

tasks, the successful experimental subjects were more active, more persistent, and tried out more methods of attacking the task than the subjects who failed to solve the novel task. This categorization of tasks helps us to see one of the benefits of experience. What is a novel task to a novice may only be a routine task to an experienced person.

This categorization also implicitly focuses on the characteristics and experiences of the decision maker involved. For example, academic economists and businessmen face different sets of tasks. The same decision-situation that presents a businessman with a problem because it deviates somewhat from a series of earlier, similar situations would present an academic economist with a novel task because he has experienced no earlier, similar situations.

Chance in Solving Problems

Chance II and IV involve movement, action, trying, persistence: things that are important in solving novel tasks. In facing a task, one thing you do is search for a series of similar situations that have been encountered earlier. This may involve attempts to form different series and attempts to reformulate some past experiences. In carrying out these activities, you are liable to do a good deal of searching (of memory, notes, books, journal articles, of colleague's ideas, and experience) and some trial and error. This involves the motion of Chance II and Chance IV. And the prepared mind and ability to form significant associations of Chance III can have a deciding effect on the success or failure of the quest.

Writing

Many people look upon writing as purely a research-reporting tool; they neglect its role as a research tool. Everything presented earlier on writing as a stimulus to the subconscious argues that writing is a valuable research tool. Certainly if you share with me the trait of not knowing what you think until you write it down, you should view writing as a research tool. Writing serves other functions in addition to stimulating the subconscious. Writing out in detail the statement of the problem, how you plan to solve the problem and why you plan to solve it in the way you do, can save work, time, money, and embarrassment.

Preparing a report covering statement of the problem, review of literature (if appropriate), theoretical analysis (economic, statistical, econometric, or operation research), data used, method of data collection, method of empirical analysis of the data—everything but results, summary, and conclusions—before beginning to collect and analyze data has several beneficial results. It causes you to solve many problems before they ever arise, and to solve them in a consistent, coherent way. It reduces the collection of unnecessary data, likelihood of failure to collect needed data, number of false starts, and performance of unneeded computations.

An alternative to writing before doing research is to do and decide simultaneously: while doing research you are also deciding how to do research. A common result is that doing gets ahead of thinking and when you finally begin to think about what you did last week, you discover that you did it wrong and last week's work has to be redone. Access to electronic computers handicaps the student, or any other researcher, who tries to plan research and perform research simultaneously. If you try to keep the computer busy, and many seem to feel the need to do so, your own busyness keeps you from doing adequate planning.

A common objective of research is the testing of hypotheses. Before you ever start testing, you ought to know which hypotheses you will test, how you will test them, why you will test them, and how you will interpret results of the tests. Writing a report before doing the research increases your chances of knowing these things and, consequently, of correctly performing and interpreting the tests of hypotheses that are most relevant for your problem. Every research project involves use of maintained hypotheses, i.e., of things that are assumed to be true for the purposes of, and during the duration of, the study. Sometimes the question of whether a specific hypothesis should be tested or maintained is critical. You are more apt to make a proper choice if you write before you act.

A reason for having my students write their theses before doing their research is this. When public funds have been assigned to me and I am responsible for them, and a student is spending those funds to gather data or perform computations, I am not comfortable unless I know what he is doing and am confident that he knows what he is doing.

Austen (p. 171) presents another reason for doing the writing before the research is completed. He writes, "The investigator must finally put all the information into a manuscript for publication complete with tables, figures, and bibliography, and must try to anticipate which editors of which journals will be the most receptive. By now, . . . *months* have gone by. The original ideas have lost their luster. Completing the manuscript is like giving birth to a cactus that has bloomed long before." Writing is much less painful if done as an early step in research than if left to the end.

Reasons Most Courses Ignore These Tools

Why do the research tools covered here receive so little attention in our graduate programs? This section represents my (speculative) explanations.

First, special purpose research tools (multiple regression, linear programming, etc.) are "public property." They are in the public domain. The tools discussed in this chapter are "private property." They are in the private domain. Thus, you can discuss my linear program or regression analysis as well as I can. And I can discuss yours as well as you can. But you cannot study and discuss my subconscious mental activities or writing habits. Nor can I study yours.

Logical analysis is public property (we all know and use the rules); intuitive analysis is private. One consequence is that "scientific types tend to downgrade subconscious mental activities because they try to keep things 'rational, within reason' (that is, consciously workable)" Austen (p. 162).

Perhaps a more fundamental reason relates to differences between the left and right halves of the mind. Austen (pp. 138–39) reports:

> Our left cerebral hemisphere 'thinks' in verbal, auditory terms, is good at translating symbols, including those of mathematics as well as language, and works best when analyzing a sequence of details. . . . In contrast, our right hemisphere 'thinks' in visual, *non*-verbal terms, particularly in terms involving complex spatial relationships, and specializes in three dimensional depth perception. It also recognizes structural similarities, and works best in Gestalt: that is, drawing conclusions based on a grasp of the total (visual) picture. . . . While its left partner proceeds, piecemeal, to examine the irregular bark on each tree, our right hemisphere grasps in one sweep the shape of the whole forest, relates it adroitly to the contours of the near landscape, then to the line of the horizon. . . . Hidden away, almost out of reach of language [in the right hemisphere], can be the source of intuitive insights that are of fundamental importance in solving a problem. And this hemisphere . . . is mute.

We see that education addresses itself almost entirely to the left half of the brain. Scientists tend to be "outward-oriented" rather than "inward-oriented." They ask, "how does the world out there work?" and not, "how does the world inside me work." As individuals, they may be curious about the latter question; but they view this as an individual concern, not a scientific concern. Related to this is the scientific constraint that research reports are to focus on the investigation, not on the investigator.

[Received April 1978; revision accepted August 1978.]

References

Austen, James H. *Chase, Chance, and Creativity: The Lucky Art of Novelty*. New York: Columbia University Press, 1978.

Beveridge, W. I. B. *The Art of Scientific Investigation*, rev. ed. New York: Random House, 1957.

Box, George E. P. "Science and Statistics." *J. Amer. Statist. Assoc.* 71(1976):791–99.

Braithwaite, R. B. *Scientific Explanation: A Study of the Function of Theory, Probability and Law in Science*. New York: Harper and Row, Publishers, 1960.

Clardy, Andrea. "In Contemplation of Her Professional Navel." Ames, Iowa, *Daily Tribune*, vol. 110, no. 92, p. 4, 19 Oct. 1977.

Guilford, J. P. "Intellectual Factors in Productive Thinking." *Explorations in Creativity*, ed. Ross L. Mooney and Taher A. Razik, pp. 95–106. New York: Harper & Row, Publishers, 1967.

Hadamard, Jacques. *The Psychology of Invention in the Mathematical Field*. New York: Dover Publications, 1954.

Hicks, J. R. *Value and Capital*, 2nd ed. London: Oxford University Press, 1950.

Keynes, John Maynard. *The General Theory of Employment, Interest and Money*. London: Macmillan & Co., 1936.

Maslow, Abraham H. "The Creative Attitude." *Explorations in Creativity*, ed. Ross L. Mooney and Taher A. Razik, pp. 43–54. New York: Harper & Row, Publishers, 1967.

Mighell, Ronald L. "Offbeat Reading for Economic Insight." *Agr. Econ. Res.* 28(1976):120–22.

Nelson, George. "Interview." *The Creative Experience*, ed. Stanley Rosner and Lawrence E. Abt, pp. 251–68. New York: Grossman Publishers, 1970.

Penfield, Wilder. "Interview." *The Creative Experience*,

ed. Stanley Rosner and Lawrence E. Abt, pp. 103–14. New York: Grossman Publishers, 1970.

Polya, G. *How To Solve It: A New Aspect of Mathematical Method*, 2nd ed. Garden City, N.Y.: Doubleday & Co., 1957.

Popper, Karl R. *The Logic of Scientific Discovery*. New York: Basic Books, 1959.

Porterfield, Austin. *Creative Factors in Scientific Research*. Durham, N.C.: Duke University Press, 1941.

Raaheim, K. *Problem Solving and Intelligence*. Bergen, Norway: Universitetsforlaget, 1974.

Siegfried, John J. "Is Teaching the Best Way to Learn? An Evaluation of Benefits and Costs to Undergraduate Student Proctors in Elementary Economics." *S. Econ. J.* 43(1977):1394–1400.

Wallas, Graham. *The Art of Thought*. New York: Harcourt, Brace & Co., 1926.

Weld, H. P. "Imagination." *The Encyclopedia Americana*, vol. 14. New York: Americana Corporation, 1956.

Wiener, N. "Induction." *The Encyclopedia Americana*, vol. 15. New York: Americana Corporation, 1956.

Young, J. Z. *Doubt and Certainty in Science*. London: Oxford University Press, 1951.

International Farm Prices and the Social Cost of Cheap Food Policies

Willis L. Peterson

The evidence suggests that real prices received by farmers in the LDCs have been substantially lower than farm prices in the developed nations. Estimates of a long-run aggregate agricultural supply elasticity from cross-section data reveal that it is relatively elastic, in the range of 1.25 to 1.66. It is estimated also that with more favorable farm prices agricultural output in a group of twenty-seven LDCs could have been 40% to 60% greater than it was and the national income of the group increased by more than 3% annually.

Key words: economic growth, food production, price distortions, social costs, supply elasticity.

For some time now we have been aware that farmers in many if not most of the world's less developed countries (LDCs) face relatively unfavorable prices (Schultz; Hayami and Ruttan; Johnson; Schuh). A number of policies and practices have contributed to this situation. Perhaps most important have been the imposition of export taxes on farm commodities which have the effect of holding domestic prices below world market levels, the overvaluation of currencies which reduces the export demand for farm products, and the use of state marketing monopolies with power to set farm prices below the levels that would be determined by competitive free markets. Also the P.L. 480 and similar programs of the developed countries (DCs) have provided subsidized, low-cost substitutes for home-produced commodities thereby lowering their prices.

The underlying motivation for these policies and practices no doubt vary between countries. In the LDCs export taxes on farm commodities have provided an easy-to-tap source of government revenue in view of their difficulties in collecting income taxes. Also these policies have been utilized in attempts to control inflation, or to hold down the price of food to industrial workers and low income people. In addition to the humanitarian motive underlying P.L. 480 and similar programs, one should acknowledge that such programs have provided a means of disposing of surplus commodities resulting from price supports on farm commodities in the donor countries.

It also happens that the prices of inputs and consumer goods purchased by farm people in many LDCs have been maintained at artificially high levels primarily through the imposition of tariffs, quotas, and embargoes on imports. Attempts to protect local industry from foreign competition, to conserve on foreign exchange, and to collect additional tax revenue appear to be the major motivations for these policies.

Some economists have argued that the long-run unfavorable price relationships faced by farmers in the LDCs have had the effect of reducing agricultural output from what it otherwise would have been, causing food shortages, and dampening agricultural as well as overall economic growth. However, we know relatively little about the magnitude of these price distortions and their impact on agricultural production in the LDCs. The main purpose of this paper is to augment the information bearing on these two questions. In the first section of the paper "real" prices received by farmers in the fifty-three countries are presented. In the following section, a long-run aggregate agricultural supply elasticity is estimated by fitting a supply function to cross-section data. In the third and final sec-

Willis L. Peterson is a professor in the Department of Agricultural and Applied Economics, University of Minnesota, St. Paul.

The author wishes to thank John Blackmore, James Houck, Glenn Nelson, and two anonymous referees for helpful comments on previous drafts of this paper without implicating them to any of its shortcomings.

tion, this supply elasticity is used to estimate the loss of agricultural output and resulting social costs in countries exhibiting relatively low farm prices.

International Farm Prices

The Food and Agricultural Organization of the United Nations (FAO) has gathered and published prices received by farmers for a large proportion of all farm commodities produced in eighty-one countries (United Nations). For most of these countries the coverage extends over the 1961–70 period. In an effort to mitigate year-to-year price fluctuations and measure over-all levels of prices, two three-year periods of price averages are constructed: 1962–64 and 1968–70.

In order to gauge accurately the economic environment experienced by farmers and make comparisons between countries, it is necessary to obtain a comprehensive measure of commodity prices. In countries where the prices of certain products are supported above market equilibrium levels, it is common to have some kind of area or production control in an effort to hold down surpluses. As a result additional land may be devoted to the production of unsupported, noncontrolled commodities causing their prices to be lower than they otherwise would be. Hence, the overall level of farm prices in these countries may not be as attractive as one first might be led to believe. Similarly, in countries where prices of certain products are held artificially low, farmers have an incentive to shift resources to the production of more profitable items.

In order to combine the prices of many diverse commodities, all prices are converted to wheat equivalent terms. The procedure is first to divide the average world market (export) price of each commodity by the average world market (export) price of wheat to obtain a price relative for each commodity for each period.[1] Then the local currency price of each commodity is converted to a wheat equivalent price by dividing by its price relative. For example, the 1968–70 world market price of maize averaged .88 that of wheat. Therefore, the local currency price of maize in each country for the 1968–70 period is converted to a wheat equivalent price by dividing by .88.

The overall average output price for each country is a weighted average price obtained by multiplying the wheat equivalent price of each commodity by the proportion of that commodity in the country's total farm output and summing over all commodities. Before calculating the quantity weights, quantities also are converted to wheat equivalent units by multiplying domestic production of each commodity by its respective world price relative. Production figures for 1963 and 1969 as presented by the FAO *Production Yearbook* are used to compute the 1962–64 and 1968–70 weighted-average prices, respectively.

The following expression summarizes the preceding computations:

$$\sum_i \frac{p_i}{\bar{p}_i/\bar{p}_w} \cdot w_i = P,$$

where p_i is the average domestic price of the ith commodity during each three-year period; $\bar{p}_i$, the average world market export price in U.S. dollars of the ith commodity during each three-year period; $\bar{p}_w$, average world market export price in U.S. dollars of wheat during each three-year period; w_i, proportion of ith commodity in total output of each country in wheat equivalent units; and P, overall average wheat equivalent price for each country during each of the three-year periods.

The resulting wheat equivalent prices for the various countries are given in terms of domestic currencies, which are not amenable to international comparison. One could convert these prices to a single currency, such as U.S. dollars, using official exchange rates. However, distortions in exchange rates also would distort the farm price figures. In countries where the dollar was overvalued during the two periods, mainly Western Europe and Japan, the dollar price of farm products would be biased downward. Conversely where the dollar was undervalued, mainly in the LDCs, dollar prices would be biased upward.

[1] The world market (export) price of each commodity is calculated by dividing the total world value of exports of that commodity (in U.S. dollars) by its corresponding quantity. The source of export prices and quantities is the FAO *Trade Yearbook*. Some commodities are not exported in the same form as priced at the farm level. Perhaps most important are meat, whole milk, and sugar crops. In an effort to make dressed meat export prices somewhat more comparable to liveweight prices, the former is divided by 2.0 before computing price relatives. In the case of whole milk the price relative is obtained by dividing the price of milk received by U.S. farmers by the world market price of wheat. The price relatives for sugar beets and cane are derived in a similar manner using U.S. and Puerto Rican beet and cane prices, respectively. Cassava (maniac) is not listed among the export commodities. To approximate the price relative of this starchy root, the world export price of potatoes is utilized.

In order to avoid the problem of exchange rate distortions, domestic currency prices are converted to price ratios by dividing by the weighted average domestic currency price of commercial fertilizer. The use of fertilizer price as a "deflator" has two advantages. First, fertilizer price data are available for a relatively large number of countries. Reasonably complete data on fertilizer prices and consumption are available in the FAO *Production Yearbook* for fifty-three of the eighty-one countries for the 1968–70 period, and for forty-four countries during 1962–64. The second desirable feature of fertilizer price is that quality of the input is reasonably constant between countries because prices are quoted on a per unit of plant food basis. Quality differences between countries for a number of other inputs probably would be so great as to preclude their use as a deflator even if the data were available. As mentioned, the overall fertilizer price is constructed as a weighted average with the weights for nitrogen, phosphorus, and potassium equal to their respective proportion in the total fertilizer consumption of each country.

Price ratios for the 1968–70 period are presented in table 1. These figures are to be interpreted as the number of kilograms of commercial fertilizer in terms of plant food that can be purchased with 100 kilograms of wheat equivalents. The higher the ratio, the higher the "real" price received by farmers. The nations are ranked from highest to lowest in terms of "real" prices received by farmers.

The figures presented clearly support the hypothesis that real farm prices are more favorable to farmers in the developed countries than to their counterparts in the LDCs with a few possible exceptions including South Korea and Pakistan. They also reveal that the price differences are significant and substantial by most interpretations of the terms. Real prices received by Japanese farmers were more than seven times greater than farmers in the Niger during the 1968–70 period. Prices received in the top ten countries averaged 3.7 times larger than prices in the lowest ten.

The same general pattern of prices exists for the 1962–64 period both in terms of ranking of the DCs and LDCs and in magnitude of the difference between the highest and lowest. For the latter, the average price received in the highest eight countries (out of forty-four) was 4.7 times greater than in the lowest eight, so there appears to have been some narrowing of price differences between countries during the 1960s.

Table 1. Real Prices Received by Farmers, 1968–70

Japan	52.5	Mexico	25.8
Hungary	51.9	Chile	25.4
Switzerland	45.5	Colombia	25.4
Finland	44.5	Morocco	25.2
United States	44.0	Greece	23.1
S. Korea	43.8	Tunisia	23.0
Norway	43.3	Portugal	22.0
France	41.2	Kenya	20.8
Sweden	40.4	Ghana	20.7
W. Germany	38.0	Panama	19.9
Belgium	37.6	Jordan	19.7
United Kingdom	36.7	Senegal	19.1
Poland	36.3	Guatemala	18.2
Denmark	35.9	Iraq	18.0
Ireland	35.9	Cameroon	16.1
Austria	35.5	Ivory Coast	15.9
Yugoslavia	32.4	Peru	15.8
Pakistan	32.2	Uruguay	15.5
Spain	31.2	Philippines	15.0
Turkey	29.8	Upper Volta	14.3
Netherlands	29.4	Argentina	13.4
Italy	29.2	Dahomey	13.0
Israel	28.5	Burma	12.2
Sri Lanka	27.9	Guyana	10.8
Canada	27.8	Khmer Republic	10.2
Cyprus	27.8	Paraguay	8.4
		Niger	7.1

Note: Real prices, or kilograms of fertilizer that could be purchased with 100 kg. of wheat equivalents.

One should, of course, bear in mind the possibility of an upward bias in these estimates as a measure of the true real prices received by farmers in the LDCs due to fertilizer subsidies in at least some of these countries. The existence of such subsidies is likely to cause the figures in table 1 to understate the true range in real prices received between the DCs and LDCs to the extent that not all inputs are subsidized in the latter countries.

Also it is likely that the terms of trade between farm commodities and consumer goods purchased by farmers in the LDCs are somewhat less favorable to farmers in these countries than to farmers in the DCs because of tariffs and embargoes on imports together with relatively high excise taxes on domestically produced consumer goods in the LDCs. Relatively unfavorable terms of trade between farm commodities and other consumer goods can be expected to dampen farmers' incentives to produce in the LDCs even more than is implied by the figures in table 1.

International Agricultural Supply Function

In order to measure the impact of low farm prices on agricultural output in the LDCs, it is necessary to have an estimate of the long-run aggregate agricultural supply elasticity. There seems to be fairly widespread agreement that this figure is some positive value, but considerable uncertainty exists over its exact size.

Most of what we know of agricultural supply elasticities has come from the estimation of supply functions utilizing time series data. Understandably, the lack of significant variation of prices within a country at a point in time requires the use of such data. However, in generating these data, markets do not perform very good "experiments" for us. What we generally observe are short term, year-to-year fluctuations in prices received. It is not unreasonable to believe that when prices are abnormally high most producers expect them to return to a more normal level in the near future. Hence we would expect producers to be reluctant to invest heavily in order to increase production for just a short period. Similarly when prices are unusually low, the reasonable expectation will be a return to somewhat more favorable prices in the near future. In this case we should not expect producers to disinvest heavily in order to reduce output during what is expected (or hoped) to be a relatively short period.

Although we do observe some output response to these short-run price fluctuations, the response should be small in comparison to what we might expect to observe when there is a change in the overall average level of prices. In the latter case it becomes more profitable to invest or disinvest in response to price changes.

It is reasonable to believe that policy action tends to change farm prices over a somewhat longer duration than market induced changes, in effect changing the overall average level of prices. Consequently we would expect the supply response to be greater in the former than in the latter case. There is some danger, therefore, of underestimating the response of farmers to policy-induced price changes if their response to short-run market induced changes is used as a guide.

The cross-section price data presented in table 1, together with the 1962–64 observations, provide an opportunity to measure the response to differences in average levels of prices. The measured response should, therefore, come closer to a true long-run supply elasticity than that obtained from short-run, year-to-year price changes. To estimate this response a simple log-linear supply function of the following specification is fitted to the cross-section observations.

$$Q = AP^{\alpha}W^{\beta}T^{\gamma}e^{\mu},$$

where Q is total agricultural output in quintals of wheat units per hectare of agricultural land;[2] A, the constant term; P, "real" prices received for all farm products in terms of kilograms of commercial fertilizer that could be purchased with 100 kilograms of wheat equivalents (for 1968–70 these are the same figures presented in table 1; comparable figures are used for the 1962–64 period); W is a weather variable approximated by the long-run average annual precipitation of each country in the sample; and T, a technology variable approximated by the number of agricultural research publications for each country in the sample.

The sources and construction of the quantity and price variables are the same as discussed in the preceding section. It ought to be emphasized that quantity is measured on a yield or per hectare basis. As a result, the function cannot measure changes in output resulting from changes in land utilization that can be expected to occur because of price changes. Consequently, the estimated supply elasticity is likely to be a lower bound of the full or true output response to price changes when both yield and area are allowed to change. Also it is likely that the land which is brought into production when price increases (or taken out when price decreases) is of a lower than average quality. If so this phenomenon will accentuate the downward bias of the estimated supply elasticity mentioned above.

Long-run average annual precipitation is used as a proxy measure of growing conditions (British Air Ministry). Admittedly this is a rough measure of growing conditions not only within large countries where weather and other characteristics, such as soil type, topography, length of growing season, vary greatly, but also between countries where there is even more variation. It might be mentioned, however, that the precipitation figure is an average

[2] In constructing the quantity variable, the wheat equivalent output of beef, pork, poultry, milk, and eggs was reduced by two-thirds to eliminate the possibility of double counting feed grains used to produce these products; quantity is net of feed grain imports.

of a large number of reporting stations, at least for large countries (104 for the United States). Also the obvious extreme readings from deserts, rainforests, and mountain tops are deleted.[3]

The other shift variable in the supply function is technology. As a proxy measure of differences in technology between countries, the agricultural research publications figures gathered by Boyce and Evenson are utilized. Total number of agricultural research publications 1948–62 are used as a proxy for the "state of the art" or stock of knowledge for the 1962–64 observations, while the total 1948–68 publications figures are applied to the 1968–70 observations. In the equations this variable enters on a per hectare of agricultural land basis.

To guard against the possibility of simultaneous equation bias as well as bias in the coefficients due to measurement errors, the coefficients are estimated by an instrumental variable (IV) (Durbin) technique in addition to ordinary least squares (OLS). Because the set of coefficients is not significantly different between the two time periods, the observations are pooled into a single regression. The log form of the equation allows us to interpret the coefficients as elasticities. The results are presented in table 2.

[3] A current year (1963 and 1969) precipitation variable also was tried but explained slightly less variation in output than the long run average figures. The source of the annual precipitation data is U.S. Dept. of Commerce, Environmental Services Administration, "Monthly Climatic Data for the World." The inclusion of the precipitation variables has relatively little effect on the price coefficient.

Table 2. Parameter Estimates for the Agricultural Supply Function

	Ordinary Least Squares		Instrumental Variables	
Explanatory Variables	Research Omitted	Research Included	Research Omitted	Research Included
Price	1.65	1.25	1.66	1.27
	(11.9)	(6.65)	(11.8)	(6.47)
Precipitation	.366	.344	.303	.293
	(2.81)	(2.74)	(2.18)	(2.19)
Research/ha.		.123		.122
		(2.95)		(2.84)
D 68–70	.372	.297	.379	.303
	(2.59)	(2.11)	(2.64)	(2.15)
R^2	.613	.646	.612	.646

Note: Figures in parentheses are t-ratios. N equals 97 in all equations.

The estimated supply elasticities ranging from 1.25 to 1.66 are substantially larger than the highly inelastic figures, in the neighborhood of about .15, that are generally obtained from aggregate agricultural supply functions fitted to time series data, even with distributed lags (Griliches 1960). However Griliches argues that the .15 estimate "underestimates severely the 'true' long-run elasticity since much of what is here attributed to trend and technological change is actually due to changes in relative prices that are not caught by the conventional price indexes" (Griliches 1960, pp. 286–8). Estimates of the aggregate agricultural supply elasticity for the United States obtained from less conventional methods range in value from 1.20 to 1.79 (Griliches 1959, Tweeten and Quance). The results obtained from the cross-section data in this study together with the evidence cited above suggest that we at least ought to entertain the possibility that the long-run aggregate supply elasticity for agriculture may be eight to ten times larger than the .15 figure which seems to be widely accepted. If it is, then the impact of policy-induced price changes on production is substantially larger than generally assumed.

In regard to the two shift variables (precipitation and research), perhaps the most interesting thing is the substantial reduction in the price coefficient that occurs when research enters the equation. In one sense this is to be expected; in another sense not. From a statistical standpoint, the positive correlation between price and research (r = .70) helps explain why the price coefficient declines when research enters the function. Research simply picks up some of the variation formerly caught by price. However, from an economic standpoint, we should expect research to have the effect of shifting supply to the right thereby reducing price for a given level of demand. In other words, price and research should be negatively correlated, other things constant. As a result, the addition of a research or technology variable could be expected to increase the price coefficient rather than decrease it.[4]

The problem is that "other things" are not constant. One might explain the positive cor-

[4] Omitting the research or technology variable when it should be included results in a specification bias for the price coefficient if research and price are correlated. The direction of the bias will be downward if there is a negative correlation between the two variables.

relation between price and research by policy differences between countries. In nations where policy favors agriculture we would expect more generous support for agricultural research as well as the enactment of price support programs, or at least absence of programs or policies which discriminate against agriculture.

A second and perhaps more likely explanation for the positive correlation between the price and research variables is that research is highly correlated with the two main demand shifters for agricultural products, namely population and per capita income. The extent of this correlation is demonstrated by the regression results presented in table 3. The dependent variable is the same research variable used in the supply function: research publications per hectare of agricultural land. Population also enters the equation on a per hectare of agricultural land basis, while income is measured as national income per capita in U.S. dollars. The price variable is the same as in the supply functions. Both equations are in log form and estimated by OLS.

The strong positive correlation of research with population and per capita income should not be unexpected. Agricultural research benefits consumers: the greater the number of consumers (population) the greater the absolute benefits of research. Perhaps even more important is the fact that in every country there are many competing uses for investment resources. The more people there are in a country and the greater their per capita income, the more resources available for investment purposes. Hence the more that will likely be made available to agricultural research. The first reason cited above (total benefits of agricultural research increase with the number of consumers) might be thought of as affecting the demand for agricultural research while the second would bear on its supply.

Table 3. Research Publications Per Hectare

	Parameter Estimates	
Explanatory Variables	Pooled Data	Developed Country Dummy Included
Population/ha.	.846 (5.47)[a]	.835 (5.39)
NI/pop.	1.56 (9.94)	1.50 (6.91)
Price	−.087 −(.206)	−.119 −(.276)
D 68–70	−.124 −(.493)	−.105 −(.409)
D.C. dummy		.175 (.365)
R^2	.765	.765

[a] The figures in parentheses are t-ratios.

The negative but insignificant coefficient on output price in the research regressions is a bit of a puzzle. A priori, one might expect price to be positively correlated with research because price should be a reflection of how much society values an increase in agricultural output. A possible explanation for the negative and insignificant coefficient on price is that if high agricultural prices are the result of price supports, the resulting surpluses of agricultural products probably dampen the demand for agricultural research.

The rather close correlation between research and the two main demand shifters is a bit worrisome at least in regard to estimating supply functions. To obtain an accurate estimate of the supply elasticity, it is necessary to include the major supply shifters in the supply function being estimated; but it is also necessary that the supply shifters are reasonably uncorrelated with the demand shifters. If one of the main supply shifters, such as research, happens also to be highly correlated with the two main demand shifters, then the resulting regression line could well be closer to a demand function than it is to a supply relation.[5] At any rate, if there is a bias in the price coefficient due to the correlation of research with population and per capita income, it is likely to be in a downward direction.

In addition to the downward bias in the supply elasticity mentioned above, one should be mindful of further downward biases caused by the measurement of output on a per hectare basis, and the likelihood that in some countries where fertilizer is subsidized farmers cannot buy all they would like at the official price. Of the countries listed in table 1, Hungary probably represents the best example of the latter problem but the situation no doubt exists in many LDCs as well.

The D.C. dummy shown in table 3 represents an interesting sidelight of the research regressions. This is a developed-country dummy variable which is assigned the value of one for the developed countries in the sample and zero for the LDCs.[6] The fact that this

[5] This problem is analogous on the supply side to Henry Moore's classic mistake on the demand side as pointed out by E. J. Working.

[6] The developed countries include all of those in the left-hand

variable is not statistically different from zero suggests that given their population and per capita income, support for agricultural research in the LDCs is comparable to the support it receives in the developed countries.[7] On the basis of this evidence, it does not appear that the LDCs are in a position to increase substantially the resources allocated to agricultural research in the near future. What we are more likely to observe is a gradual increase in agricultural research as more resources become available due to population and income growth, particularly the latter. This is not to deny that growth of income will be maximized for a given level of investment only if the rates of return to the various components of total investment are equalized. If the rate of return to investment in agricultural research is greater than it is in other investments, then a nation can increase its rate of economic growth by allocating more resources to agricultural research and less to other investments.

Social Costs

In using the estimated supply elasticity presented in this paper to compute the loss of agricultural output and net social costs due to low farm prices in the LDCs, we should keep in mind that this coefficient represents an average supply response across all the countries in the sample. One might question whether the supply response is in fact the same between countries. For example, it is sometimes argued that peasant farmers in the LDCs are less responsive to price than their commercial counterparts in the developed nations. However, partitioning the data between the DCs and LDCs, running separate regressions, and applying F test, revealed no significant difference in the set of coefficients between the two groups of countries.[8] In fact, the observed difference in the supply elasticity ran in the direction of a larger elasticity for the LDCs, although the difference was not statistically significant at the conventional levels. At least it seems fairly safe to say that the estimated supply elasticity definitely is not smaller in the LDCs than in the DCs, and may even be larger.

To obtain a rough idea of the magnitude of the reduction in annual agricultural output in the LDCs stemming from low farm prices, the potential level of 1969 output for the twenty-seven countries shown in the right-hand column of table 1 is computed using the lower IV estimate of the supply elasticity (1.27) as obtained from equation (4) of table 2. Potential output is estimated using both the average price for the twenty-six countries in the left-hand column of table 1 (36.89), and the overall average price for the fifty-three country sample (27.04) as benchmarks. The percentage difference between actual and potential output for each country in the right-hand column of table 1 is estimated to be 1.27 times the percentage difference between the actual and bench mark prices using the benchmark price as the base. One can interpret these figures as the annual loss of food production (in wheat equivalents) in the LDCs resulting from unfavorable farm prices. The results are presented in the first two columns of table 4. The computations reveal that if the twenty-seven countries in the right-hand column of table 1 had enjoyed the average price which prevailed in the twenty-six countries on the left (36.89) over an extended period, their 1969 output would have been about 220 million metric tons greater than it was, which amounts to a 63% increase over actual output. Using the overall sample average as the benchmark price (27.04) yields a potential output for these countries that is about 140 million metric tons greater than actual output which is equal to a 40% increase.

On the basis of this evidence, one strongly suspects that if farmers in the LDCs had enjoyed the level of prices that prevailed in the developed nations, or even in the world market, there would be no such thing as a world food shortage. The likelihood of this being true is reinforced by the fact that the twenty-seven countries listed on the right-hand column of table 1 have substantially more agricultural land per capita than the twenty-six countries on the left. The twenty-seven countries on the right had an average of .95 persons per hectare of agricultural land in 1969, whereas the corresponding figure for the twenty-six countries on the left was 3.40. Indeed one might go so far as to say that if farm prices in the LDCs were to approach world market levels these countries

column of table 1 except South Korea, Pakistan, Spain, Turkey, Sri Lanka, and Cyprus.

[7] The size and significance of the D.C. dummy remains virtually unchanged when price is excluded from the regression.

[8] The countries are grouped as specified in footnote 6. The computed F statistic is 1.5, whereas the "critical" value of F with 4 and 92 degrees of freedom is about 3.5 at the .01 level of significance and 2.5 at the .05 level.

Table 4. Loss of Agricultural Output and Social Cost of Price Distortions in 27 LDCs, 1969

Country	Loss of Output in Wheat Equivalents with a Bench Mark Price of 36.89 (1000 MT)	27.04 (1000 MT)	Social Cost in U.S. Dollars[a] Total ($1000)	Percentage of NI
Mexico	18,258	2,787	8,347	.03
Chile	3,388	663	2,871	.05
Colombia	9,403	1,839	7,963	.12
Morocco	5,001	1,073	4,764	.16
Greece	12,635	4,932	48,727	.58
Tunisia	1,489	588	6,007	.52
Portugal	7,399	3,406	42,728	.74
Kenya	3,820	2,024	31,453	2.45
Ghana	4,752	2,793	43,711	2.53
Panama	1,610	922	16,071	1.89
Jordan	888	516	9,278	1.48
Senegal	3,658	2,233	43,468	5.63
Guatemala	3,042	1,962	42,468	2.94
Iraq	4,952	3,231	71,372	2.73
Cameroon	4,439	3,188	84,578	8.77
Ivory Coast	6,916	5,008	136,194	10.34
Peru	8,581	6,241	170,441	4.74
Uruguay	4,576	3,369	94,601	4.49
Philippines	21,158	15,879	460,412	5.76
Upper Volta	1,646	1,294	40,217	6.63
Argentina	53,206	42,097	1,392,358	6.21
Dahomey	1,713	1,372	46,449	25.24
Burma	23,801	19,531	700,187	38.16
Guyana	1,135	965	38,025	17.77
Khmer Republic	7,395	6,449	263,442	33.60
Paraguay	4,311	3,847	188,733	37.08
Niger	2,284	2,084	100,626	28.92
Total	221,556	140,293	4,095,644	

[a] Assuming $5.88 per 100 kilograms of wheat equivalent as an equilibrium price. This is comparable to the 27.04 price ratio.

likely would become substantial exporters of agricultural products.

Should the governments of LDCs change their policies and allow their internal agricultural prices to approach world market levels (net of transport costs) the resulting increases in agricultural output in these countries would seem to have important repercussions on farmers and consumers in the United States and other developed countries. For one thing, the exports of agricultural products by the United States and other developed countries to LDCs either in the form of P.L. 480 shipments or through commercial channels could be expected to decrease substantially. Perhaps more important would be the increased supplies of agricultural products on the world market which would compete with U.S. and other developed-countries' products both at home and abroad. The end result would be lower prices for U.S. and other developed-country farmers, unless there were severe restrictions on imports of agricultural products from LDCs. Of course consumers in the developed countries should benefit from lower food prices. By the same token, farm supply industries in the developed nations probably would experience some slackening of demand in their domestic markets. However these firms should find greatly expanded opportunities in the LDCs, provided they are allowed to do business in these countries.

The increased production of agricultural products would not, of course, be free. In the short run, resources would have to be drawn from other industries, or imported, in order to increase agricultural output. But even after paying for these resources either in terms of an opportunity cost of domestic nonagricultural production or in the expenditure of foreign exchange, the LDCs still would have something left over as a net gain. One can view this

potential net gain as the social cost of holding real price below the market equilibrium level.[9]

The social cost for countries which hold farm prices below their market equilibrium is *illustrated* by the shaded triangle in figure 1. Bear in mind that points on the supply curve represent the opportunity cost or value of output given up to produce a marginal unit of the product, whereas points on the demand curve are a measure of the value to society of the marginal unit of that item. Maintaining price at P_0 results in output Q_0. The opportunity cost of producing a marginal unit of Q_0 is P_0, while the value to consumers of this unit is P_2. Thus, the net gain to society of producing one more unit beyond Q_0 is equal to the difference between P_2 and P_0. The expansion of output from Q_0 to Q_1 continues to result in net gains to society albeit in smaller and smaller increments.

The information necessary to calculate the value of the shaded triangle includes the elasticities of demand and supply as well as values of P_0, P_1, P_2, Q_1, and Q_0. Unfortunately, it is not possible to estimate a demand elasticity from the international data. Because of the disequilibria resulting from government price policies, a price-quantity relationship cannot be observed along a demand curve. A demand elasticity figure can be chosen, however, which would likely be an upper bound of the true figure. A price elasticity of demand of minus one should in turn yield a lower bound of the true social costs.

In order to compute social costs, it is necessary to use a monetary price for each of the values of P_0, P_1, and P_2 rather than a price ratio or pure number as presented in table 1. A U.S. dollar price per 100 kilograms of wheat equivalent is computed for each country in the sample by first dividing each country's domestic currency wheat-equivalent price by the official exchange rate. The same procedure is utilized to compute a U.S. dollar price of fertilizer for each country. Then a price-paid index is constructed by dividing each country's fertilizer price, now in U.S. dollars, by the sample average price for that period and multiplying by 100. The U.S. dollar wheat equivalent price series is then deflated by the prices-paid index by the usual procedure of dividing through by the index and multiplying by 100. The resulting deflated dollar price

[9] There also is a social cost of holding price above the market equilibrium level. See Bale and Greenshields for an estimate of this cost to Japan.

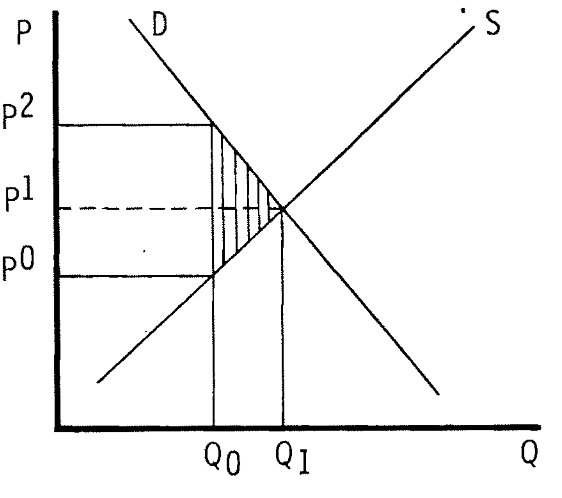


Figure 1. The social cost of cheap food policies

figures are free of any bias caused by exchange rate distortions because the bias runs in the same direction for both the wheat equivalent and fertilizer prices; in the deflating process the bias cancels out.

With regard to price, the crucial figure is P_1, the equilibrium price for each country. No doubt this price varies between countries depending on how much of the nations' food is imported or exported, and differences in transportation costs. The overall average price of \$5.88 per 100 kilograms of wheat equivalent for the fifty-three country sample is selected as a plausible equilibrium price. (This is equivalent to the 27.04 price ratio). The true equilibrium probably is above this value for some countries and below it for others. Utilizing the observed values of P_0 and Q_0, the estimated supply elasticity of 1.27, and the assumed values of minus one and \$5.88 for the demand elasticity and equilibrium price, the dollar value of social cost resulting from price distortions is estimated for each of the twenty-seven countries listed on the right-hand side of table 1. The results are presented in the third and fourth columns of table 4. The figures in the third column are the annual (1969) social costs for each country in terms of U.S. dollars, and in the fourth column these figures are expressed as a percentage of each country's national income for 1969. These figures represent the estimated annual reduction in the value of output or "dead weight loss" resulting from price distortions.

For the twenty-seven countries as a group, the \$4,095 million social cost for 1969 is equal

to 3.76% of their combined national income. At first glance this appears to be a small figure, but it is interesting to note that a nation which is able to add 3.76% to its real national income each year, by eliminating social costs or for any other reason, will more than double its output every twenty years. Of course, as is shown by the figures in table 4, the estimated social costs differ greatly between countries. As expected, the cost is more significant in countries where the distortion is greatest (doubling the distortion much more than doubles the social cost) and where agriculture makes up a large share of national income.

Summary and Conclusions

The evidence suggests that real prices received by farmers in the LDCs have been substantially lower than prices received by farmers in the developed nations. Differences in real farm prices in the order of magnitude of four to five times are common between the most and least favored nations. The evidence also supports the hypotheses that the long-run aggregate supply elasticity for agriculture is greater than one, and that unfavorable farm prices have reduced significantly agricultural output and economic growth in many LDCs.

Governments of LDCs are well aware of the political problems that arise when attempts are made to reverse policies that have kept the real price of farm products artificially low. But unless they are reversed, perhaps gradually over a period of time, there is little hope for these countries to produce an adequate supply of food for their people or to achieve sustained economic growth.

[*Received October 1977; revision accepted June 1978.*]

References

Bale, Malcolm D., and Bruce L. Greenshields. "Japanese Agricultural Distortions and Their Welfare Value." *Amer. J. Agr. Econ.* 60(1978):59–73.

Boyce, James K., and Robert E. Evenson. *Agricultural Research and Extension Programs*. New York: Agricultural Development Council, 1975.

British Air Ministry Meteorological Office. *Tables of Temperature, Relative Humidity, and Precipitation for the World*. London: Her Majesty's Stationery Office, 1958.

Durbin, J. "Errors in Variables." *Rev. Int. Statist. Inst.* 22(1954):23–32.

Griliches, Zvi. "The Demand for Inputs in Agriculture and a Derived Supply Elasticity." *J. Farm Econ.* 41(1959):309–22.

———. "Estimates of the Aggregate U.S. Farm Supply Function." *J. Farm Econ.* 42(1960):282–93.

Hayami, Yujiro, and Vernon W. Ruttan. *Agricultural Development: An International Perspective*. Baltimore, Md.: Johns Hopkins University Press, 1971.

Johnson, D. Gale. *World Food Problems and Prospects*. Washington, D.C.: American Enterprise Institute for Policy Research, 1975.

Schuh, G. Edward. "General Economic Policy as a Constraint to the Development of Agriculture." *Agricultural Policy: A Limiting Factor in the Development Process*. Washington, D.C.: Inter-American Development Bank, 1975.

Schultz, Theodore W. *Economic Growth and Agriculture*. New York: McGraw-Hill Book Co., 1968.

Tweeten, Luther G., and C. Leroy Quance. "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches." *Amer. J. Agr. Econ.* 51(1969): 342–52.

United Nations, Food and Agriculture Organization. *Agricultural Producer Prices, 1961–70*. Rome, 1975.

Working, E. J. "What Do Statistical Demand Curves Show?" *Quart J. Econ.* 41(1927):212–35. (Reprinted in *Readings in Price Theory*, ed. George J. Stigler and Kenneth J. Boulding, pp. 97–115. Homewood, Ill.: Richard D. Irwin, 1952.)

Modeling International Grain Trade with Government Controlled Markets

Philip C. Abbott

Government interventions have a pervasive impact on international grain trade, yet models of that trade treat the role of government as an exogenous influence. A model endogenizing government is presented as an alternative to spatial equilibrium trade models. That model is also used to interpret parameters in a net import demand model and to argue that the effect of international prices and production on trade often will be smaller than what is derived from domestic supply and demand equations. Econometric evidence supporting that contention is presented for trade in wheat and feed grains by thirty-three countries.

Key words: feed grains, government intervention, trade controls, trade model, wheat.

International grain trade flows have been estimated in the past by methodologies appropriate to long-run projection. Because of the nature of international grain markets, and particularly the existence of large grain stocks and the potential for oligopolistic behavior on the part of the major exporters, these methodologies in conjunction with educated guesses on the part of the analyst could be used to project short-run behavior as well. Under those market conditions, accurate estimation of the behavior of the smaller traders was not important, because fluctuations in international prices were relatively small. Because the depletion of grain stocks in the hands of the major exporters during the early and mid-1970s placed severe restrictions on their behavior, estimation of the behavior of the smaller traders becomes considerably more important if short-run shifts in international grain prices and trade flows are to be predicted. Explicit attention must be paid to the behavior of governments with respect to grain markets and to the imperfections in those markets, in order to make such predictions. A model of trading behavior emphasizing the problems with that standard methodology will, therefore, be presented. That model will allow interpretation of parameter estimates in net trade models in the light of domestic market behavior and government intervention. It might also be used to suggest respecification of the models utilized in the standard approach. The approach used here could be useful in the analysis of nonagricultural markets, as well, when government intervention in international trade is present.

Existing Grain Trade Estimation Methodologies

The projection methodologies used in the agricultural economics literature and by government and international organizations have utilized estimates of domestic supply and demand equations for traders with deviations of domestic prices from international prices either ignored or entered exogenously into the model. One example is that used for the projections of grain supply, demand, and trade done by the United States Department of Agriculture (USDA) (USDA ERS 1971a). More recent unpublished work by USDA estimates net grain imports as a function of international price and other variables. No interpretation of the estimates obtained have been made, however.

Trade flows are estimated in the USDA model using the spatial equilibrium framework as introduced by Bawden. Such a scheme assumes international agriculture markets are efficient and have no distortions (i.e., free trade), or it imposes additional constraints to capture the effects of market distortions. Those constraints assume, for example, that traditional exporters will retain certain mar-

---

Philip C. Abbott is an assistant professor of economics at Northeastern University.

kets in spite of efficiency considerations. Though that methodology handles well many of the analytical problems in modeling grain trade, as presently used it is inadequate to capture endogenously the effects of government intervention on trade behavior. Specific constraints must be added or altered exogenously to model such effects.

Several studies in the agricultural economics literature have analyzed international grain trade in a similar manner, including those of Schmitz and Bawden; Bjarnason; Coffin; and Blakeslee, Heady, and Framingham. The results of the important study by Timmer and Falcon, however, indicate some of the problems with this approach. They show that the price of rice relative to the price of fertilizer varies considerably between countries, and this ratio goes a long way toward explaining variations in rice yields between countries. They suggest that local governments exert considerable control over prices, so that international prices are separated by policy. This may be of considerable importance in estimating trade flows, especially for the small traders. Kravis and Lipsey have shown that this phenomenon of separated and apparently independently moving domestic and international prices is not unique to agricultural commodities.

Two other works in the agricultural economics literature are also of interest in citing the inadequacy of using domestic supply and demand equations alone, and of not worrying about how domestic and international prices are connected in estimating international grain trade. Abel has pointed out that use of the export subsidy by the USDA has allowed grain sellers to discriminate between an open domestic market (where prices have been kept high) and weak international markets (where prices are lower). McCalla (1966) has pointed out that the United States, Australia, and Canada, who sell approximately 73% of total wheat exports, should be modeled as cooperating oligopolists when large grain stocks are held. He suggests that the Canadian Wheat Board has acted in the past as a price setter, with other major exporters following their lead.

McCalla's work suggests that in times when grain stocks were large, as was the case before the events of 1973–74 "world food crisis," small price changes would result in compensating behavior on the part of the major exporters, leaving the price to other traders relatively unchanged. With depleted stocks, adjustment in net exports by the major traders must come out of extremely inelastic domestic consumption markets. The small trade elasticities of other traders are no longer dominated by large elasticities of the major exporters, as Tweeten has suggested. Accurate estimation of those elasticities then becomes more important, and the assumption that free market behavior is sufficient to find the response of a country's net import demand to changes in international prices may no longer be valid.

An Alternative Domestic Agriculture Model

An alternative to the straightforward treatment of supply and demand generally used is presented here as a means of deriving a more appropriate model determining a country's net import demand. This model will be used to interpret parameters of a net import demand model. The basic structure of this model still will be one in which trade balances supply and demand, but that balance will be achieved in only a segment of the national market. Domestic and international prices may be separated by standard devices, either tariffs or quotas, but the extent to which those devices are used will be determined endogenously. Behavioral agents considered by this model will include consumers, farmers, and government policy makers who control prices with tariffs, quotas, and other trade restrictions. Consideration of a self-sufficient sector whose consumption fluctuates directly with its production, and the behavior of policy makers who allow consumption to increase or decline directly with production, where self-sufficiency is a national policy and the government is unwilling to spend scarce foreign exchange to stabilize those fluctuations, will be included in this model as well.

Notation to be used in this derivation is presented in table 1.

Price Behavior

The relationship between domestic and international prices is extremely important in determining how a country responds to shifting world market conditions. The spatial equilibrium framework normally assumes the domestic price of a commodity (PD) equals the

Table 1. Variable Notation

XT	Net Imports of Commodity x in Country i[a]
XP	Production
XC	Consumption
XQ	Domestic Supply to Trading Market
XS	Stocks on Hand
XR	Net Stocks Released
XA	Aid in Kind Received
PW	World Market Price of Commodity x
PP	Producer Price of Commodity x
PD	Consumer Price of Commodity x
PI	Price Index for Inputs Used by Farmers
POP	Population
INC	National Income at Constant Prices
FX	Foreign Exchange Flows (Total Exports plus Foreign Capital Inflows)
AN	Stock of Animals (in relative feed units)
EX	Expenditure on Commodity x (in $ millions)
T	Time Trend

[a] Because cross-price effects are ignored, no commodity subscript is used. Also, because all variables pertain to a single country, no country subscript is used.

world market price of that commodity at that country's border (*PW*) or the world price times one plus an ad valorem tariff (τ). The world price assumed here is either the import price or export price at a country's border. Hence, that price would include consideration of transport costs, but would differ from a domestic price if a tariff or quota were in effect.

A country may choose, however, to ignore the world market and control its domestic prices, in which case *PD* would not be a function of *PW*. This can be achieved by using a constant quota determined from the domestic market, or utilizing a variable levy system such as the one in operation in the European Economics Community (EEC), in which case $PD = PW\ (1 + \tau)$ would still apply, but τ would be a policy instrument used to maintain the desired *PD*. In a world in which self-sufficiency and protection of domestic agriculture are important policy goals, this may be a considerably more reasonable assumption that what is used in the spatial equilibrium framework. In developing countries, where food riots may result from sudden increases in food prices, domestic price stability may in fact be a requirement.

Neither of these assumptions may be adequate in some cases. The minimum import price schemes of the United Kingdom (before it joined the EEC) and Japan imply partial adjustment to world market prices. It may be in these cases that there are limits to the extent to which domestic prices can follow world prices, or it may be that in any period only a partial adjustment may be allowed, but in the long run domestic prices must follow world market prices. A model that corresponds to this later assumption would be partial adjustment model

$$(1) \qquad PD_t = \lambda PD_{t-1} + dPW_t.$$

Short-run adjustment to world price in this model is given by

$$(2) \qquad \frac{\partial PD_t}{\partial PW_t} = d.$$

In this case, or in a less restrictive model with other factors affecting *PD*, the response of domestic price to world prices is likely to be some fraction between 0 and 1 (unless overshooting in adjustment is allowed, and it will be excluded here). The extremes represents the two cases cited earlier. When $d = 1$ and $\tau = 0$, a free market exists; and if $d = 1 + \tau$, a constant ad valorem tariff in an otherwise free market exists. When $d = 0$, a stable domestic price, or at least one that does not move with world prices, exists. A value of d between 0 and 1 implies some partial adjustment of domestic price to world price. This specification will then be useful in interpretation of estimates, in that it will suggest tests to determine which model obtains in a given market.

Other Factors Affecting Price

Both a country's trade with the rest of the world and domestic factors may also affect a controlled domestic price. An importing country facing a foreign exchange constraint may be unwilling to maintain a low domestic price if production is low or foreign exchange receipts are low in a given year. This is less likely to be the case when only a small fraction of foreign exchange is spent on the commodity in question, however. Production may affect the level chosen for a controlled domestic price, so that in bad years a higher price may be allowed than in good years. In countries where stocks are held, the level of those stocks may also be a consideration in the determination of a domestically controlled price.

If stocks are included as a possible government policy, then the above arguments suggest the following simple equation as an alternative explanation of short-run adjustments of the domestic price:

$$(3)\quad PD_t = dPW_t + e_0 + e_1XP + e_2FX + e_3XS + e_4XA,$$

where e_1, e_2, and e_3 are parameters measuring the influence of XP, FX, and XS on price. If the price to producers is controlled and moves independently of PD, then the same considerations which influence the consumer price must also influence the producer price, and a similar equation can be derived. If stocks are held, then the same considerations also apply to the release of stocks and a similar equation may again be derived.[1]

Hence, a government has the choice of three instruments in controlling the domestic market: the release of stocks, XP; the consumer price, PD; and the producer price, PP. Any selection of these three instruments implies a necessary trade policy to maintain these variables which is implicit in the relations between domestic and world prices included above. By following a free market, they lose one or two instruments, because PD and possibly PP are tied to PW. Equation (3) and similar equations explaining PP and XR, therefore, are models of the government's trading and stock release behavior. Parameters are dependent upon policy, so if there is a policy change in a country, its behavioral model must also be changed.

Price Responses

It can be shown that in this model, the effect of world market price on consumption is the product of the response of the domestic market to changes in domestic price and response of the domestic price to the world market price. The effect of world market price on supply is the combination of the marketed surplus response and response of producer price to world market price in the short run, and would include the response of production to producer price, as well, in the long run. If constant elasticity functions are assumed in place of the demand and supply specifications used above, then the relation between net imports and the world market price is given by

$$(4)\quad \frac{\partial XT}{\partial PW_t} = \frac{XC_o}{PW_{ot}}\,(d\epsilon - d'\nu\eta),$$

where ϵ is the domestic price elasticity of demand, d' is the short-run adjustment of the producer price (PP) to changes in PW, ν is a fraction of consumption produced domestically, and η is likely to be less than long-run η. The lagged adjustment mechanism in equation (1) and a similar equation for PP implies

$$(5)\quad \left.\frac{\partial XT}{\partial PW}\right|_{long\ run} = \frac{XC}{PW}\left(\frac{d}{1-\lambda}\,\epsilon - \frac{d'}{1-\lambda'}\,\nu\eta\right),$$

where λ is the lagged adjustment parameter in the equation explaining PP. If one believes that no matter how one tries to disconnect prices from world market trends, in the long run he must follow those trends, then $\left(\frac{-d}{1-\lambda}\right)$ and $\left(\frac{d'}{1-\lambda'}\right)$ will both equal 1. If, however, countries do isolate themselves in the short run from the world market (or the long run, for that matter) responses may be less elastic than the USDA model or others would imply, even if short-run supply elasticities are assumed to be zero and low demand elasticities are used.

For simplicity the lagged price term in equation (1) and in a similar equation for the supply price will be excluded from subsequent derivations. The consequence of this assumption is that λ and λ' will not be estimated and the estimated parameters must be interpreted as short-run effects. Bias is introduced by this approach only if lagged and current exogenous variables are dependent.

In a model predicting agricultural trade flows, the above reasoning suggests that elasticities used should be net responses to world market prices at a country's border rather than responses to domestic prices. A further simplification corresponding to that practice, which shall subsequently be assumed, is

$$(6)\quad \frac{\partial XT}{\partial PW_t} = \frac{XC_o}{PW_o}\,\bar{d}\,(\epsilon - \nu\eta).$$

Under this assumption, the interpretation of $\bar{d}$ is the extent to which PW and any domestic prices are disconnected, and its magnitude should be similar to d and d'. At the extremes, $d = d' = 0$ or 1, so that the extremes for $\bar{d}$ are also 0 or 1.

Production and Supply

In the standard model, where production and domestic supply are equated, trade will vary

[1] Equations explaining policy determined producer prices of stock releases might be

$$PP = d' \cdot PW + e'_0 + e'_1XP + e'_2FX + e'_3XS + e'_4XA$$
$$XR = d'' \cdot PW + e''_0 + e''_1XP + e''_2FX + e''_3XS + e''_4XA.$$

inversely with production, with a one-to-one correspondence. Fluctuations in production are generally assumed to be predetermined by exogenous factors such as weather. Supply in this model will be only some fraction of production which depends on the urban/rural terms of trade, as characterized by a marketed surplus response by producers. Hence,

$$(7) \qquad XQ = (a_1 + a_2\, PP/PI)\, XP,$$

where a_1 and a_2 are parameters to be estimated, and XQ is domestic supply affecting trade.

In order to derive an expression for the response of trade to production, a model of consumption behavior for the trading segment of the national market is required. The model of consumption to be used in this approach requires somewhat different data but the same structure as a more conventional approach. A demand function such as the following may be used:

$$(8) \quad XC = g_1PD + g_2POP + g_3INC + g_4T + g_5AN.$$

Balance for the above markets when the behavior of stockholders as additional producers is included is given by

$$(9) \qquad XT = XC - XQ, \text{ or}$$

$$(10) \quad XT = \epsilon_1PD + g_2POP + g_3INC + g_4 \cdot T + g_5 \cdot AN - (a_1 + a_2PP/Pi)(XP + XR).$$

One may note that with the exceptions that production might not have a one-to-one correspondence with trade and the parameters in the demand equations may be relevant to only a segment of the domestic market, this model is identical to the standard supply and demand treatment of trade determination. The standard assumptions of the USDA projection model are allowed but not assumed by this specification.

The effects of variations in production on net trade may now be assessed using this model. First, there is the direct effect that at constant prices and varying production, the marketed surplus may also vary with that production, as more or less is available for sale. Second, the government may try to reduce demand by raising the consumer price when production is low. The producer price may also be used in a similar manner. That is, when production is low, the producer price is raised to obtain more of that production as marketed surplus, and hence, trade is not used to satisfy demand in the cities. If a' is the net effect of production on trade, then

$$(11) \quad \frac{\partial XT}{\partial XP} \equiv a' = g_1e_1 - \frac{a_2}{PI}\, e'_1XP - a_1 + \frac{a_2}{PI}\,(e'_0 + e'_2FX + dPW).$$

The term g_1e_1 represents the effect of varying the consumer price, $\frac{a_2}{PI}\, e_1 \cdot XP$ represents the effect of varying the producer price, and the remaining terms determine the standard marketed surplus at fixed prices and varying production as discussed above. For simplicity, it will be assumed that a' remains roughly constant, or that the marginal effect of variations in production remain the same over time. An alternative specification of the supply equation in which the response of marketed surplus to price did not depend on the level of production would also give this result. If the response to price of marketed surplus is zero, as some would suggest, this result would also be obtained. The net effect in this model for trade is that the effect of production on trade may be less than the one-to-one correspondence suggested by the USDA model. Showing that effect is all that is hoped for here.

Foreign Exchange Effects

Another effect which may work through the government's control mechanism is the effect of inflows of foreign exchange on expenditures on imports of a commodity. That is, when foreign exchange receipts are low, a country may be more willing to accept a high consumer price and be less willing to spend foreign exchange to lower that price. It also may alter its control over the producer price, depending upon its foreign exchange flows. Hence, the net effect of foreign exchange would be

$$(12) \quad \frac{\partial XT}{\partial FX} \equiv j' = g_1e_2 - a_2\frac{XP}{PI}\, e'_2,$$

where g_1e_2 results from the effect of foreign exchange on the consumer price and $a_2\frac{XP}{PI}$ e'_2 comes from the effect of foreign exchange on the producer price. Again, for simplicity, j' will be assumed constant.

Foreign Aid

The treatment of aid in kind for the estimation of trading behavior for developing countries may also be important. Since such aid has entered through import channels or as donations to governments who then act as suppliers, it may be merely an increase in supply, increasing XT. Fisher has pointed out that if the aid in kind were given away free to those who would not otherwise have consumed the product, in effect creating additional demand for the commodity, then both supply and demand must be altered.

It also may be the case that only part of the aid in kind received by a country is used in demand-creating ways. If, for example, the aid is given as an income transfer and some of that additional income is used to consume goods other than commodity X, then only partial demand creation may occur. That is, only some fraction b of the aid in kind received becomes additional demand, and if XT data includes the supply of aid, as is the case for available import statistics, then

$$XT = XC - XQ + bXA. \tag{13}$$

It should be noted that aid does not create demand as in equation (13), when imports received as aid are in fact not additional imports, but instead substitute for commercial imports which otherwise would have been purchased. In the case where a government controls imports and the aid received does not affect importing decisions, or where the government fixes domestic prices (in which case commercial imports rather than prices must adjust), then commercial imports will decline in an amount equal to the quantity of aid in kind received, because no additional demand is created.

A Derived Trade Equation

Using the simplifying assumptions and parameter definitions presented above, a specification of the generalized reduced form net trade equation would be

$$\begin{aligned} XT = {} & c' - d^*PW\frac{XC_o}{PW_o} \\ & + bXA - a'XP + j'FX + k'XS \\ & \quad + g_2POP + g_3INC + g_4T + g_5AN. \end{aligned} \tag{14}$$

The arguments presented above also suggest signs and ranges for some of the parameters in equation (14) and, therefore, an interpretation of coefficients estimated from a net import demand equation. The parameter d^* must be greater than or equal to zero, and should be less than or equal to $(\epsilon - \nu\eta)$. ($d^* \equiv \frac{-\partial XT}{\partial PW_t}\,\frac{PW_o}{XC_o} = \bar{d}(\epsilon - \nu\eta)$; XC_o and PW_o are base year data used to convert parameters to elasticity form.) Hence, a comparison of d^* to earlier estimates of supply and demand parameters is possible. The parameter b should be between 0 and 1, with zero implying aid substituting for commercial imports, and 1 implying complete demand creation. The parameter a' also should be between 0 and 1, with the value 1 implying the standard approach. The parameter j' should be greater than zero, and a comparison of the implied increase in expenditure of foreign exchange to the increase in foreign exchange flows is possible. Parameters g_2, g_3, and g_5 should have positive values, as suggested by demand theory.

Equation (14), therefore, is an alternative equation determining net trade behavior which can be used to estimate import demand (or export supply) parameters, test hypotheses concerning the relevance of assumptions made in the standard models of trade determination, and suggest refinements in such models.

Estimation Problems and Results

Estimation of this trade model was conducted for two commodities, wheat and feed grains, and in thirty-three countries or regions, using annual data from 1951 to 1973. (Shorter estimation periods were used when data was unavailable. See Abbott for details and the exact specifications used.) Instrumental variables estimation techniques were used, because estimation of net import demand equations which depend on world market price are subject to simultaneous equation bias. Several other problems were dealt with in determining appropriate data and estimation procedures. These are discussed in detail elsewhere by this author and are available on request.

The estimation results are also available in their entirety in that paper—only parameter estimates for the important hypotheses considered here will be included. Parameter estimates have been converted to forms which

allow comparison with prior information and which allow tests of hypotheses presented earlier. Price response coefficients are converted to consumption-based elasticities, as suggested by definition of d^*. Data for 1972 were used in these conversions.

The econometric estimates obtained are weak, due to the nature of the available data and the simplifying assumptions invoked. Strict hypothesis tests which discriminate between alternative hypotheses can be conducted in only a limited number of cases. In many cases, standard errors are too large to make the necessary comparisons, though the large errors will in those cases support weakly the null hypothesis that no relationship exists between trade and the variable under consideration. Where strict hypothesis test results are obtained, they will be presented. Other relevant results also will be discussed. In the hypothesis tests presented, a 10% level of significance will always be used in order to allow discrimination in a greater number of cases. In some of the cases where strict hypotheses tests are possible, stricter significance levels are possible. These results, therefore, must be viewed with much care and skepticism, but do present some evidence on the hypotheses suggested below.

Trade Price Elasticities

The linear price response coefficients obtained in estimations have been used to determine consumption-based net import demand price elasticities (d^*). That elasticity measures the percentage decrease in consumption (at fixed production) for a 1% increase in border price. This parameter can be compared to the USDA domestic demand elasticity ($-\epsilon$) in order to determine if an open market exists, in which case $d^* = -\epsilon$, if a completely controlled or closed market exists and $d^* = 0$, or if partial adjustment applies and $0 < d^* < -\epsilon$. The weighted sum of USDA demand and supply elasticities ($-\epsilon + \nu\eta$) also will be presented so that a comparison to long-run response of the border price in the USDA model can be made.

These results and data used in comparisons are presented in table 2 for developing-country model estimations and in table 3 for developed-country model estimations. The standard errors of those estimates are reported in parentheses next to the estimates.

Table 2. Trade Price Elasticity Estimation for Developing Countries

	Wheat			Feed Grains		
Country	d^{*a}	$(-\epsilon)^b$	$(-\epsilon + \nu\eta)^b$	d^{*a}	$(-\epsilon)^b$	$(-\epsilon + \nu\eta)^b$
Latin America						
Argentina	−0.83 (0.60)[c,d]	0.3	0.69	0.43 (0.52)	0.4	0.79
Brazil	−2.48 (2.04)	0.2	0.27	0.25 (0.17)[d]	0.3	0.60
Mexico	1.54 (0.596)[d]	0.4	0.51	−0.32 (0.23)	0.5	0.80
Colombia	−0.52 (0.49)	0.2	0.23	1.90 (1.15)[d]	0.4	0.59
Guatemala	2.75 (3.20)	0.4	0.52	0.16 (0.16)	0.5	0.79
Chile	−0.28 (0.29)	0.2	0.31	−0.37 (0.72)	0.4	0.51
Asia						
India	−.069 (0.146)	0.5	0.69	−.071 (0.147)	0.2	0.40
Pakistan	0.14 (0.49)	0.5	0.68	3.40 (4.34)	0.2	0.40
Thailand	1.60 (0.78)[d]	0.5	0.50	0.76 (0.51)[d]	0.2	—
Indonesia	−.058 (.036)	0.5	0.50	0.015 (0.162)	0.4	0.60
Philippines	0.15 (0.76)	0.5	0.50	−0.033 (0.125)	0.4	0.58
Iran	0.32 (0.278)	0.2	0.29	0.31 (0.54)	0.2	0.30
Turkey	0.19 (0.74)	0.2	0.30	−.045 (.072)	0.2	0.30
Africa						
Egypt	1.17 (0.41)[d]	0.2	0.35	0.42 (0.75)	0.3	0.40
Kenya	0.27 (0.94)	0.4	0.48	−1.00 (1.12)	0.2	0.30
Ghana	−0.87 (4.22)	0.4	0.40	0.91 (0.54)[d]	0.2	0.30
Europe						
Portugal	−.063 (.304)	0.3	0.53	0.059 (0.071)	0.7	0.82

[a] d^* is the consumption elasticity, which equals $\dfrac{-PW_*}{XC_*}\dfrac{\partial XT}{\partial PW}$. Negative signs indicate perverse results.

[b] ϵ is the domestic demand price elasticity, ν is the fraction of consumption produced domestically, and η is the domestic supply elasticity as reported by USDA (1971).

[c] Standard errors of estimates are presented in parentheses after the estimates.

[d] Significantly different from zero at a 10% level of significance.

Table 3. Trade Price Elasticity Estimates for Developed Countries

	Wheat			Feed Grains		
Country	d^{*a}	$(-\epsilon)^b$	$(-\epsilon + \nu\eta)^b$	d^a	$(-\epsilon)^b$	$(-\epsilon + \nu\eta)^b$
United States	−0.16 (0.67)[c]	0.2	0.73	0.012 (0.057)	0.4	0.72
Canada	0.56 (3.47)	0.2	1.60	−2.30 (1.12)	0.5	1.08
Australia	9.61 (9.84)	0.1	2.34	1.56 (1.28)	0.1	0.57
United Kingdom	0.27 (0.26)	0.2	0.41	0.45 (0.17)[d]	0.7	0.93
Japan	0.069 (0.280)	0.33	0.35	−0.60 (0.20)	0.7	0.71
EEC	0.073 (0.215)	0.3	—	−0.22 (0.14)	0.5	0.72
France	−0.46 (0.43)	0.3	—	0.27 (0.41)	0.5	—
West Germany	−0.047 (0.323)	0.3	—	−0.25 (0.21)	0.5	—
Italy	0.024 (0.112)	0.3	—	0.066 (0.224)	0.5	—
Netherlands	−6.19 (7.01)	0.3	—	−1.27 (1.04)	0.5	—
Belgium-Luxembourg	0.20 (0.29)	0.3	—	−0.56 (0.31)	0.5	—
USSR	−0.016 (0.060)	0.2	0.39	−0.11 (0.13)	0.4	0.58
Sweden	0.37 (0.60)	0.3	—	0.50 (0.46)	0.7	—
Denmark	1.68 (1.06)[d]	0.3	—	0.31 (0.30)	0.7	—
Austria	−0.098 (0.396)	0.3	—	0.19 (0.11)	0.7	—
Norway	0.056 (0.386)	0.3	—	−0.047 (0.021)	0.7	—

Note: for notes, see table 2.

Cases in which the hypothesis that a free market or market with a constant tariff exists ($d^* \geq -\epsilon$) is accepted and the hypothesis that domestic and world prices are unrelated is rejected include wheat: Mexico, Thailand, Egypt, and Denmark; feed grains: Brazil, Colombia, Thailand, Ghana, and the United Kingdom. In all of these cases, except for the United Kingdom and Thailand feed grain models, unreasonably large price responses are found. Cases in which the free market hypothesis ($d^* = -\epsilon$) can be rejected and the hypothesis ($d^* < -\epsilon$) can be accepted include wheat: Argentina, Brazil, Colombia, Chile, Indonesia, EEC, France, West Germany, Italy, and Netherlands; feed grains: Mexico, Guatemala, India, Kenya, Portugal, Canada, Japan, EEC, West Germany, Italy, Netherlands, Belgium-Luxembourg, USSR, Austria, and Norway.

In the following cases, very small trade prices responses [$d^* < 0.5(-\epsilon)$], with standard errors too large to make strict hypothesis tests, were found. These are also cases in which it seems reasonable to expect ($d^* < \epsilon$) and the controlled market hypothesis seems relevant. They are wheat: Pakistan, Philippines, Iran, Portugal, United States, Japan, USSR, Austria, and Norway; feed grains: Chile, Indonesia, Philippines, Turkey, and the United States.

These results suggest that domestic prices and net imports are unrelated to border prices in many countries. In developing countries, in particular, this inelastic importing (or exporting) behavior seems to be verified. Hence, the low elasticities which are used in the USDA model appear to be still too high in many cases. This suggests countries, and especially developing countries, are unwilling to alter their domestic agricultural policies, at least in the short run, in response to fluctuating world market conditions. This result is consistent with the notion expressed by several agricultural and development economists that a stable domestic (and especially urban) price is an important policy target which cannot be allowed to fluctuate with external conditions.

Estimates for some of the major exporters, especially in wheat, suggests these countries make much of the quantity adjustment required when changes occur in the world market. Their stock-holding behavior allows elasticity estimates greater than those suggested by the supply and demand elasticities. Others of the major traders and a few developing countries also appear to either maintain free markets, or to adjust quantity in response to varying conditions in world markets. Ignoring standard errors, reasonably large responses to border prices were found for wheat: Mexico, Guatemala, Thailand, Turkey, Egypt, Kenya, Canada, Australia, United Kingdom, Belgium-Luxembourg, Sweden, and Denmark; feed grains: Argentina, Brazil, Colombia, Pakistan, Thailand, Iran, Egypt, Ghana, Australia, United Kingdom, France, and Sweden. It is interesting to note that most of

the above countries are, or were, exporters for at least one of the grains, with the notable exceptions of the United Kingdom and Egypt.

Clearly, some of the estimation results are unacceptable. The low price elasticities for the United States, in particular, seem unreasonable. Also, the several cases where small countries have elasticities much greater than $(-\epsilon)$ are unlikely results. Nevertheless, results have been obtained in many cases which suggest that adjustments to changing world market prices are not likely to be made according to a model based on domestic supply and demand parameters.

Trade and Production

Two reasons why a one-to-one correspondence between trade and production, as suggested by the USDA-type models, might not be found were given earlier. It should be noted before proceeding that econometric considerations and collinearity problems make estimates of this effect the least reliable of those considered here. The estimates obtained all appear to be extremely low, and there may be a systematic bias in that direction. Those estimates were often consistent with price response estimates which suggest a closed and self-sufficient market, however.

The estimates obtained are presented in table 4 for the seventeen developing countries, and table 5 for the sixteen developed-country cases. Standard errors are reported in parentheses next to the estimates.

If these results are to be believed, they provide overwhelming evidence rejecting the one-to-one correspondence models for most cases. Strict rejection of that hypothesis (ignoring possible bias) is possible in wheat: Argentina, Colombia, Chile, India, Iran, Turkey, Kenya, Portugal, Canada, Australia, United Kingdom, Japan, EEC, France, West Germany, Italy, USSR, Sweden, Denmark, and Austria; feed grains: Argentina, Brazil, Mexico, Guatemala, Pakistan, Thailand, Indonesia, Philippines, Iran, Turkey, Kenya, Ghana, Australia, United Kingdom, France, West Germany, USSR, Sweden, Denmark, Austria, and Norway.

Certainly, some estimates are unacceptable again, and the possible bias makes interpretations of these results difficult. Nevertheless, it is unlikely that these results could be obtained so consistently if the assumption that all pro-

Table 4. Effect of Production Shortfalls on Net Imports for Developing Countries

Country	Production Coefficient for:[a] Wheat	Feed Grains
Latin America		
Argentina	0.079 (0.204)[b]	0.109 (0.132)
Brazil	1.03 (0.976)	0.159 (0.600)
Mexico	0.612 (0.463)[c]	0.483 (0.251)[c]
Colombia	−0.314 (0.769)	0.687 (0.826)
Guatemala	1.457 (4.548)	−0.021 (0.118)
Chile	0.489 (0.231)[c]	1.017 (0.327)[c]
Asia		
India	0.367 (0.169)[c]	0.947 (0.234)
Pakistan	1.59 (0.91)[c]	−20.68 (11.97)[c]
Thailand	—	0.232 (0.208)
Indonesia	—	−0.045 (0.078)
Philippines	—	0.00051 (0.228)
Iran	0.441 (0.359)	−0.105 (0.458)
Turkey	−0.354 (0.087)[c]	−0.020 (0.044)
Africa		
Egypt	0.526 (0.929)	0.308 (0.921)
Kenya	0.426 (0.261)[c]	0.336 (0.266)
Ghana	—	0.152 (0.276)
Europe		
Portugal	0.387 (0.098)[c]	0.658 (0.279)[c]

[a] The production coefficient equals $(-\partial XT/\partial XP)$ and can be interpreted as the fraction of production shortfalls made up by imports.
[b] Standard errors for the estimates are reported in parentheses after the estimates.
[c] Significantly different from zero at a 10% level of significance.

Table 5. Effect of Production Shortfalls on Net Imports for Developed Countries

Country	Production Coefficient for:[a] Wheat	Feed Grains
United States	—	0.073 (0.058)[b]
Canada	0.148 (0.115)	0.433 (0.270)[c]
Australia	−0.079 (0.171)	0.065 (0.114)
United Kingdom	0.214 (0.338)	0.129 (0.310)
Japan	0.231 (0.241)	1.102 (0.860)
EEC	0.391 (0.203)[c]	0.659 (0.236)[c]
France	0.221 (0.136)[c]	0.204 (0.206)
W. Germany	0.387 (0.147)[c]	0.067 (0.224)
Italy	0.131 (0.224)	1.574 (0.630)[c]
Netherlands	2.764 (8.935)	−0.094 (1.221)
Belgium-Luxembourg	1.115 (0.389)[c]	0.140 (0.707)
USSR	0.121 (0.092)	0.049 (0.145)
Sweden	0.266 (0.167)[c]	0.187 (0.185)
Denmark	0.140 (0.294)	0.187 (0.259)
Austria	0.148 (0.241)	0.694 (0.152)[c]
Norway	−0.606 (1.164)	0.231 (0.217)

[a] The production coefficient equals $(-\partial XY/\partial XP)$ and can be interpreted as the fraction of production shortfalls made up by imports.
[b] Standard errors for the estimates are reported in parentheses after the estimates.
[c] Significantly different from zero at a 10% level of significance.

duction shortfalls are made up in trade (less price effects) were true. It seems more reasonable to presume that either a self-sufficiency policy or an enclave model is relevant in many cases, especially when such a policy is the stated policy of many countries.

Conclusions

Because of the nature of the problem being investigated and the data which must be used, strong econometric evidence is unlikely. Nevertheless, consistent results demonstrating the inadequacy of the assumptions of the standard methodology used to protect international grain trade flows in the short run have been found. In addition, evidence on the actual behavior of several individual countries has been obtained.

The hypotheses that suggest a modified approach to estimation of international grain trade flows incorporating government trading policies endogenously and that have been verified for some cases are the following. (*a*) A desire (or need) to maintain a stable domestic consumer price for grain may cause governments to alter tariffs and quotas endogenously, or use other policies under their control (such as stockholding policies or the urban/rural terms of trade) to divorce effectively the world market price for grain and the determination of net import demands. (*b*) Those same policies and segmentation of domestic markets will cause variations in net import demand to be substantially less than variations in production. That is, a government self-sufficiency policy and physical separation of markets can eliminate or reduce the one-to-one correspondence between production shortfalls and import levels. (*c*) Importing countries that must allocate limited foreign exchange to payments for grain may be influenced by export receipts and foreign capital inflows or by the receipt of foreign aid in the form of grain in making import decisions.

Incorporation of these hypotheses into procedures for the estimation of international grain trade flows and pricing in the short run is likely to lead to improved results, and simplified ways to do that have been suggested and attempted in this paper.

[Received March 1978; revision accepted August 1978.]

References

Abbott, Philip C. *Developing Countries and International Grain Trade*. Ph.D. thesis, Massachusetts Institute of Technology, June 1976.

Abel, Martin E. "Price Discrimination in the World Trade of Agriculture Commodities." *J. Farm Econ.* 48(1966):194–200.

Bawden, D. L. "A Spatial Price Equilibrium Model of International Trade." *J. Farm Econ.* 46(1964):1372–79.

Behrman, Jere. *Supply Response in Underdeveloped Agriculture*. Amsterdam: North-Holland Publishing Company, 1968.

Bjarnason, Harold. *An Economic Analysis of 1980 International Trade in Feed Grains*. Ph.D. thesis, University of Wisconsin, 1969.

Blakeslee, L. L., Earl O. Heady, and C. F. Framingham. *World Food Production, Demand and Trade*. Ames: Iowa State University Press, 1973.

Coffin, H. *An Econometric Analysis of Import Demand for Wheat and Flour in World Markets*. Ph.D. thesis, University of Connecticut, 1970.

Fisher, F. M. "A Theoretical Analysis of the Impact of Food Surplus Disposal on Agricultural Production in Recipient Countries." *J. Farm Econ.* 45(1963):863–75.

Kravis, Irving, B., and Robert E. Lipsey. "Export Prices and the Transmission of Inflation." *Amer. Econ. Rev.* 67(1977):155–63.

McCalla, Alex F. "A Duopoly Model of World Wheat Pricing." *J. Farm Econ.* 48(1966):711–27.

———. "Pricing in the World Feed Grain Market." *Agr. Econ. Res.* 19(1967):93–102.

Schmitz, Andrew F., and D. L. Bawden. *The World Wheat Economy: An Empirical Analysis*. Giannini Foundation Monograph No. 32, University of California, Berkeley, March 1973.

Timmer, C. P., and W. P. Falcon. "The Political Economy of Rice Production and Trade in Asia." Paper prepared for the ADC/RTN workshop on Trade and Development, University of Chicago, Feb. 1973.

Tweeten, Luther. "The Demand for U.S. Farm Output." *Food Res. Inst. Stud.* 8(1967):343–70.

U.S. Department of Agriculture. *World Demand Prospects for Grain in 1980 with Emphasis on Trade by the Less Developed Countries*. For. Agr. Econ. Rep. No. 75, March 1971a.

———. *The World Food Situation and Prospects to 1985*. For. Agr. Econ. Rep. No. 89, March 1971b.

Vannerson, F. *An Econometric Analysis of the Postwar United States Wheat Market*. Ph.D. thesis, Princeton University, 1969.

Approximately Optimal Carryover Levels for Wheat in the United States

C. Robert Taylor and Hovav Talpaz

This paper presents results of stochastic simulations of adherence to a first-period first-order certainty equivalence decision rule for approximately optimal wheat stocks in the United States. The decision rule is obtained by maximizing a first-order approximation of the discounted sum of expected producers' plus consumers' surplus less storage costs over a long-time horizon. For comparative purposes, stochastic simulations of the present system for holding stocks are also given in the paper. Stock levels under the present system were found to be higher than the certainty equivalence stock levels.

Key words: carryover, stocks policy, wheat reserves.

Recent fluctuations in grain production in the United States and abroad have renewed interest in establishing reserved stocks of grain, for such reserves can stabilize prices and also help to insure that supplies will be adequate for consumption should there be an especially bad harvest. In discussing the need for a national food policy, Houthakker considered the role of grain carryover stocks and the necessity to improve the existing partial policies. The renewed interest on the subject has caused a flurry of research articles on this topic. In particular, Reutlinger has used a simulation model to analyze the effects of alternative world wheat reserve stock policies. Using another approach, namely a quadratic programming spatial and temporal world equilibrium model, Takayama and Liu have estimated optimal (from an international viewpoint) wheat storage levels in each of thirteen countries. The only recent effort to determine the optimal wheat storage rule for the United States, given the existing structure of international trade, was made by Johnson and Sumner using the framework developed by Gustafson in the 1950s. This framework, though, has a few weaknesses. In particular, it does not account for supply response and associated production cost nor uncertainty about demand.

This paper presents a framework for determining approximately socially-optimal grain stocks that is a substantial improvement over the Gustafson model, in that it does account for supply response, attendant production cost, and demand uncertainty. The model is used to determine approximately socially optimal level of wheat storage for the United States. The decision criterion is the maximization of an approximate expression of the expected present value of a perpetual stream of consumers' and producers' surpluses subject to the behavior of the U.S. wheat sector.

After presenting the optimal stock model, simulated stocks for the next ten years under the present system are compared with socially optimal stocks. This comparison gives some indication of the social desirability of the current system. Aside from this comparison, this paper is not concerned with institutional arrangements by which the optimal carryover policy could be implemented. The paper concludes with a discussion of the weaknesses of the model and some suggestions for future research of this important topic.

The Certainty Equivalence Scheme

The basic framework underlying the decision model is the first order certainty equivalence principle (Malinvaud, Prescott, Simon, and

C. Robert Taylor is an assistant professor of agricultural economics at Texas A&M University, and Hovav Talpaz is an associate professor of agricultural economics at Texas A&M University and the Volcani Center, Israel.

Texas Agricultural Experiment Station Technical Article No. 13243.

The authors would like to express their appreciation to Bruce Gardner and two anonymous reviewers for their constructive comments.

Theil). The classical certainty equivalence theorem states that the optimal decision in a risky situation is the same as in some associated riskless situations (Malinvaud, p. 706). This theorem holds true under rather specific conditions: quadratic payoff and linear relations between the decision (control) variables and results. However, Malinvaud showed that even when these conditions are not met but the various functions involved are twice differentiable then this property holds to the first order of approximation; moreover, it can be applied to the dynamic case as well. Actually, Malinvaud proved this generalization for the class of problems where the deviations of the results and the payoff from their respective expected values are proportional to the size of the error term. He concluded that under some specific conditions the optimal values of the control variables for the first time period are, to the first order of approximation, independent of the degree of uncertainty. Note that the optimization of the dynamic problem will involve the decision on the future control variables as well; however, the first order approximation applies only to the first period control variables. This means that the decision maker has to reapply the optimization process in a moving horizon fashion to readjust the later decision variables when they belong to the next first period.

Framework for Decisions

For this study, it is assumed that the objective of society in controlling wheat stocks is to maximize the present value of the combined consumers' and producers' surpluses less storage costs. The objective function to be maximized takes into account (*a*) wheat farmers' behavior as represented by an acreage response function, (*b*) demand, and (*c*) a stock identity. Surplus is used as an objective function because it is an empirically operational approximation to the welfare society derives from producing and consuming wheat (Harberger). Since last year's price influences current wheat acreage and because of the stock inventory relationship, decisions which are made with respect to surplus in only one year would be myopic; therefore, the present value of surplus is used in the objective function. In addition to the assumption that the marginal utility of money is equal for all consumers and producers, it is necessary to assume that the marginal utility of money is constant over time, and society discounts future utility at some specific rate. A discount rate of 8% was somewhat arbitrarily selected for this study.

A formal specification of the optimization model is deferred until after the wheat sector model, used in the analysis, is presented.

The Econometric Model

The econometric model used as a basis for this study is comprised of an undated and slightly modified specification of a wheat demand study by Barr and a wheat acreage response study by Garst and Miller. Readers interested in a detailed discussion of the logic of the model specifications are referred to these studies. All equations in the model were estimated with Zellner's procedure for seemingly unrelated regressions, because it is likely that the disturbances among equations are correlated. The model can be expressed by the following equations.[1] Acreage response:

$$(1)\quad \begin{aligned} lnAC_t &= \underset{(165.23)}{3.4105} + \underset{(19.28)}{0.0088X_{1t}} - \underset{(13.51)}{0.0121X_{2t}} \\ &\quad - \underset{(2.87)}{0.0029X_{3t}} + \underset{(20.68)}{0.6333X_{4t}} + \underset{(12.98)}{0.1175X_{5t}} \\ &\quad + \underset{(10.20)}{0.185np_{t-1}}; \quad R^2 = .98, \end{aligned}$$

yield per acre:

$$(2)\quad lnY_t = \underset{(3.62)}{-3.3845} + \underset{(7.07)}{1.5676lnT}; \quad R^2 = .73,$$

demand for domestic food use:

$$(3)\quad \begin{aligned} lnQF_t &= \underset{(43.97)}{5.0107} - \underset{(2.51)}{0.0126lnP_t} \\ &\quad + \underset{(10.92)}{0.2946lnT}; \quad R^2 = .87, \end{aligned}$$

demand for domestic feed use:

$$(4)\quad \begin{aligned} lnQFE_t &= \underset{(2.40)}{-12.6166} - \underset{(2.72)}{0.6447lnP_t} \\ &\quad + \underset{(3.23)}{4.0197nT}; \quad R^2 = .50, \end{aligned}$$

seed demand:

$$(5)\quad lnQSE_{t-1} = \underset{(2.43)}{-0.1682} + \underset{(63.13)}{1.0765lnAC_t}; \quad R^2 = .99,$$

[1] Numbers in parentheses are *t*-values. The *R*-square values are for the ordinary least squares estimates of the equations.

export demand:

$$(6)\quad lnQEXP_t = \underset{(0.70)}{2.0551} - \underset{(3.13)}{0.1502}lnP_t + \underset{(4.88)}{0.4459}D_t + \underset{(3.13)}{3.1725}lnT - \underset{(5.05)}{1.5316}lnWPRW_t \qquad R^2 = 81,$$

wheat production outside the United States:

$$(7)\quad lnWPRW_t = \underset{(4.94)}{-4.6906} + \underset{(10.98)}{2.475\,1}lnT; \qquad R^2 = .86,$$

private stock holding behavior:

$$(8)\quad lnS_t = \underset{(31.34)}{7.5183} - \underset{(7.11)}{1.4590}lnP_t - \underset{(6.76)}{0.2261}lnGS_t; \quad R^2 = .75, \text{ and}$$

stock identity relation:

$$(9)\quad A_tY_t + S_{t-1} + GS_{t-1} \equiv QF_t + QFE_t + QSE_t + QEXP_t + S_t + GS_t,$$

where ln is natural logarithm; AC_t, planted acreage of wheat in year t (million acres); X_{1t}, U.S. wheat acreage allotment (1000 acres); X_{2t}, optional or additional diversion on allotment acres under diversion programs (1000 acres); X_{3t}, total acres of wheat set-aside under the program (1000 acres); X_{4t}, dummy variable representing the change in the model structure accompanying removal of acreage allotment for the current government program; X_{5t}, dummy variable representing the removal of marketing quota penalties from the allotment program and allowing substitution of wheat for feed grains; P_{t-1}, average price received by farmers for wheat during the previous season (constant 1967 dollars); Y_t, wheat yield (bushels per planted acre); QF_t, quantity of wheat demanded for food use (million bushels); QFE_t, quantity of wheat demanded for feed use (million bushels); $QEXP_t$, quantity of wheat demanded for export (million bushels); QSE_t, quantity of wheat demanded for seed use (million bushels); QD_t, total quantity of wheat demanded (million bushels); S_t, ending private stocks of wheat (million bushels); GS_t, ending government stocks of wheat (million bushels); $WPRW_t$, total wheat production in the world excluding the United States (million metric tons); T, time trend variable (calendar year–1960); Q_t, wheat production (million bushels); and D_t, dummy variable representing a shift in export demand ($D_t = 1$ for 1972–74; $D_t = 0$, otherwise).

All equations in this model were estimated with annual data for the 1960–74 period. Equation (8) is used in simulating the stock levels that would exist in future years under the present system for holding stocks, but is not used in determining the socially optimal stock levels.

Linear demand and supply relationships of the wheat sector were not used for this analysis because it was found that the quantity demanded at a zero price was only slightly greater than recent production levels. Consequently, implausibly low and even negative prices were found in some of the simulations of both the current system and the optimal system. Thus, the more plausible log-linear form was selected for the econometric model.

The Decision Model

Now let us consider an algebraic expression of the objective function for the certainty equivalence model. This is society's net welfare discounted and summed up through the planning horizon which combines for each year the area between the demand and supply curves less the storage costs. For the certainty equivalence formulation of the objective function, all random variables in the model are replaced with their respective expected values. Because the supply and demand functions are nonlinear, replacing random variables with their expected values does not give expected surplus; thus, the certainty equivalence objective function is at best a first-order approximation to expected surplus (Malinvaud). An exact expression for expected surplus could be obtained only by integrating surplus (as a function of seven error terms) over the multivariate distribution, an exercise which is analytically as well as numerically impractical. Consequently, the first-order approximation of surplus is used in this study. The usual way in which a surplus objective function is formulated for a storage problem is with quantity and stocks as the state and decision variables, respectively. But because of the algebraic form of the econometric model and because demand is separated into four components, it is easier to specify the objective function with price as the decision variable and stocks as the state variable. In examining the appendix, it

should become apparent that these two specifications are equivalent. We denote the objective function in general form as

$$(10) \qquad W^* = \sum_{t=1}^{T} W_t(P_t, P_{t-1}, S_t, S_{t-1})r^t$$
$$= \sum_{t=1}^{T} r^t[f_t(P_t) - g_t(P_{t-1}) - cS_t],$$

where P_t is price (dollars per bushel); S_t, total stocks (million bushels); $f_t(P_t)$, area under the demand curve as a function of P_t; $g_t(P_{t-1})$, area under the supply functions at time t as related to P_{t-1} and t; c, annual storage cost (dollars per bushel); r, discount rate; and T, length of planning horizon (years).

By making the appropriate integration of the product of equations (1) and (2), which is the expected supply curve, it can be shown that

$$(11) \qquad g_t(P_{t-1}) = \frac{a_1 a_0 b_0 t^{b_1} P_{t-1}^{(a_1+1)}}{(a_1 - 1)},$$

where a_0, a_1 are coefficients of the acreage response function, equation (1),[2] and b_0, b_1 are coefficients of yield time trend, equation (2).

The integration under the demand curves would involve definite integrals with infinite price. However, one can integrate the demand curve from an arbitrary high price, H, to the actual price and obtain a finite measure that can validly be used in an optimization model (see appendix). Also, one can compare validly the areas for different prices and find the change in surplus associated with going from current system to a government-managed system. Integration in this manner gives

$$(12) \quad f_t(P_t) = \frac{g_0 H^{(g_1+1)} t^{g_2}}{(g_1 + 1)} + \frac{g_1 g_0 P_t^{(g_1+1)} t^{g_2}}{(g_1 + 1)} + \frac{v_1 H^{(v_1+1)} t^{v_2}}{(v_1 + 1)} + \frac{v_1 v_0 P_t^{(v_1+1)} t^{v_2}}{(v_1 + 1)} + \frac{e_0 a_0^{e_1} H^{(a_1 e_1+1)}}{(a_1 e_1 + 1)} + \frac{a_1 e_1 a_0^{e_1} e_0 P_t^{(a_1 e_1+1)}}{(a_1 e_1 + 1)} + \frac{w_0 H^{(w_1+1)} t^{w_2} (z_0 t^{z_1})^{w_3}}{(w_1 + 1)} + \frac{w_1 w_0 P_t^{(w_1+1)} t^{w_2} (z_0 t^{z_1})^{w_3}}{(w_1 + 1)},$$

where, g_0, g_1, g_2 are coefficients of the food demand curve, equation (3); v_0, v_1, v_2 are coefficients of the feed demand curve, equation (4); e_0, e_1, coefficients of the seed demand curve, equation (5); w_0, w_1, w_2, w_3, coefficients of the export demand curve, equation (6); and z_0, z_1, coefficients of the time trend for wheat production in the rest of the world, equation (7).

The stock identity (9) also must be considered in the optimization. Note that by substituting equations (1) through (7) into (9) we obtain

$$(13) \quad S_t = S_{t-1} + a_0 P_{t-1}^{a_1} b_0 t^{b_1} - g_0 P_t^{g_1} t^{g_2} - v_0 P_t^{v_1} t^{v_2} - e_0 (a_0 P_t^{a_1})^{e_1} - w_0 P_t^{w_1} t^{w_2} (z_0 t^{z_1})^{w_3}.$$

By successively lagging equation (13) one period and substituting the result into the right-hand side of (13) for S_{t-1}, one can obtain current stocks as a function of previous and current prices, and initial stock S_0. Substituting this result along with (11) and (12) into (10) gives the function to be maximized as a function of prices and initial stocks:

$$(14) \quad W^* = \sum_{t_0=1}^{T} r^t \Bigg\{ \frac{g_0 H^{(g_1+1)} t^{g_2}}{(g_1 + 1)} + \frac{g_1 g_0 P_t^{(g_1+1)} t^{g_2}}{(g_1 + 1)} + \frac{v_0 H^{(v_1+1)} t^{v_2}}{(v_1 + 1)} + \frac{v_1 v_0 P_t^{(v_1+1)} t^{v_2}}{(v_1 + 1)} + \frac{e_0 a_0^{e_1} H^{(a_1 e_1+1)}}{(a_1 e_1 + 1)} + \frac{a_1 e_1 a_0^{e_1} e_0 P_t^{(a_1 e_1+1)}}{(a_1 e_1 + 1)} + \frac{w_0 H^{(w_1+1)} t^{w_2} (z_0 t^{z_1})^{w_3}}{(w_1 + 1)} + \frac{w_1 w_0 P_t^{(w_1+1)} t^{w_2} (z_0 t^{z_1})^{w_3}}{(w_1 + 1)} + \frac{a_1 a_0 b_0 t^{b_1} P_{t-1}^{(a_1-1)}}{(a_1 - 1)} - c \sum_{t=1}^{t_0} \Big[a_0 P_{t-1}^{a_1} b_0 t^{b_1} - g_0 P_t^{g_1} t^{g_2} - v_0 P_t^{v_1} t^{v_2} - e_0 (a_0 P_t^{a_1})^{e_1} - w_0 P_t^{w_1} t^{w_2} (z_0 t^{z_1})^{w_3} \Big] - cS_0 \Bigg\}.$$

The certainty equivalence decision rule can be obtained by maximizing W^* with respect to the price vector $(P_1, P_2, \ldots, P_T)$, given the initial conditions P_0 and S_0. A quasi-Newton-Raphson method (Fletcher) was used to determine the price vector that maximizes W^*. This method was selected because it is fairly efficient for this type of problem. Also, it computes the necessary derivatives numerically, and so it could be easily embedded in the simulation model.

Maximization of W^* gives the optimal price in period 1, P^*_1 as well as optimal prices for all succeeding periods. However, with the cer-

[2] The effects of nonstock policy variable in equation (1) are incorporated into the intercept term a_0 for this derivation.

tainty equivalence framework, only P^*_1 is used.

Using equation (13), the optimal level of stocks S^*_1 is computed based on P^*_1. To simulate the behavior of the system into the future when adhering to the first-period, first-order certainty equivalence decision rule, S^*_1 is computed given P^*_1 and S_0. The "actual" or real world situation is then simulated by drawing the error terms for equations (1) through (7) from their multivariate, log-normal distribution. (This is done by using a random number generator sub-routine for the multivariate normal distribution with zero means and variance-covariance matrix obtained from the third stage of Zellner's estimation procedure, transformed to give the log-normal deviates.) Solving the stock identity equation (9) with actual demand, supply, and the optimal stock S^*_1, the actual price P_1^a is numerically computed using a specially designed algorithm which is based on the Newton (root-seeking) method. With this information, P^*_2 and S^*_2 are computed, and this process is continued for the T periods of interest.

In comparison to the optimal stocks system, the behavior of the present system for making stock decisions is simulated by simply replacing the social decision rule obtained by maximizing (14), with the private stock behavioral relationship, equation (8). The results of these simulations for ten years into the future and for fifty independent simulations are shown in the next section. For these results, we used a moving time horizon of seven years in the optimization model. Sensitivity analysis revealed that longer horizons would not significantly change the first period optimal price and stock level; yet, longer horizons substantially increase the computer time necessary to find the optimal price vector.

With respect to stochastic elements in the simulation models, we make the assumption that the means and variances of the parameters of the model are equal to their respective estimated values. This is a compromise between the untenable assumption that the model is deterministic and the unworkable—and perhaps untenable—assumption that no information exists about the model. Some advances are being made in formulating adaptive models (Chow, Prescott), but these are not considered here because of the difficulty in obtaining the required subjective probability information and the expense of solving such a model.

To give validity to the statistically estimated coefficients as well as the decision model that follows, it is additionally assumed that the various error terms are not autocorrelated. To the extent that there are cycles in weather, the error terms for the per acre yield equation are autocorrelated; however, Luttrell and Gilbert concluded that there is little evidence for nonrandomness in the crop yield series. Until these effects are isolated, it seems reasonable to make the operational assumption that the errors are not autocorrelated. Moreover, since other sources of variation and impact are largely relative to these factors, the bias is not likely to be significant. The error introduced by this assumption is implicit in all of the wheat sector simulation and optimization models that have been constructed (Gustafson; Johnson and Sumner; Ray, Richardson, Collins; Reutlinger; Sharples, Walker, Slaughter; and Tweeten, Kalbfleish, Lu). However, the assumption of no autocorrelation is not crucial here and, should future evidence prove the contrary, it could be easily incorporated into the model.

Results

The results of fifty simulations of the current system (CS) and the certainty equivalence (CE) decision rule for ten years into the future are shown in table 1. Figure 1 gives average carryover stocks for CS and CE. With CS, stocks increase to a high of 889 million bushels in 1984/85 and then begin to slightly decline. However, stocks under the CE rule decrease in the initial years and stabilize at about 350 million bushels, indicating that stock levels under the current system are too high. The early sharp decrease is due to the too high initial stock given to the system.

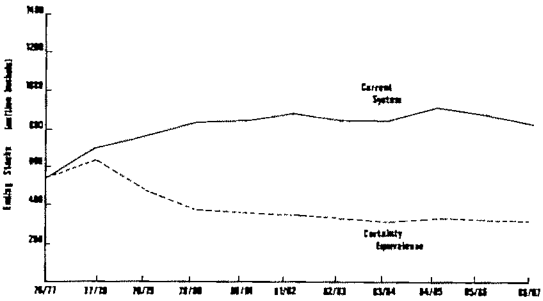


Figure 1. Average carryover stocks for 50 simulations

Table 1. Simulation Results for 1977–87 and Ten-year Averages

Item	1977/78		1978/79		1979/80		1980/81		1981/82	
	CS	CE	CS	CE	CS	CE	CS	CE	CS	CE
Price:[a]										
mean	2.67	1.86	2.51	2.12	2.37	2.52	2.44	2.66	2.27	2.51
standard deviation	.59	1.36	.51	1.05	.51	1.30	.66	1.31	.61	1.26
Production:[b]										
mean	1,870	1,895	1,858	1,653	1,827	1,766	1,798	1,780	1,834	1,792
standard deviation	126	108	131	207	131	154	125	176	129	180
Exports:[b]										
mean	1,029	1,094	1,006	1,079	996	1,072	1,023	1,069	1,010	1,059
standard deviation	115	74	121	77	147	88	137	106	142	76
Domestic consumption:[b]										
mean	717	765	732	762	737	761	751	774	756	778
standard deviation	34	61	35	52	37	66	44	72	52	60
Ending stocks:[b]										
mean	687	606	774	436	835	389	844	381	875	372
standard deviation	197	100	211	202	211	182	281	187	295	198
Net welfare:[c]										
mean	51,565	51,582	52,452	52,798	51,795	53,339	52,438	53,615	52,430	53,073
standard deviation	3,913	4,500	3,541	3,696	3,859	3,998	3,851	4,410	4,138	4,078
Producers' surplus:[c]										
mean	4,107	2,703	3,882	2,934	3,608	3,857	3,708	3,965	3,456	3,732
standard deviation	905	2,658	946	1,779	938	2,337	1,055	2,353	1,040	2,243
Domestic consumers surplus:										
mean	22,140	23,544	22,500	23,501	22,500	23,450	22,680	23,584	22,860	23,902
standard deviation	450	907	400	907	430	1,056	533	1,098	592	852

Table 1. Simulation Results for 1977–87 and Ten-year Averages (continued)

Item	1982/83 CS	1982/83 CE	1983/84 CS	1983/84 CE	1984/85 CS	1984/85 CE	1985/86 CS	1985/86 CE	1986/87 CS	1986/87 CE	Ten-Year Average CS	Ten-Year Average CE
Price:[a]												
mean	2.34	1.99	2.43	2.43	2.41	2.42	2.24	2.50	2.40	2.35	2.41	2.34
standard deviation	.66	1.23	.44	1.34	.59	1.24	.65	1.30	.60	1.22	.58	1.26
Production:[b]												
mean	1,764	1,768	1,794	1,723	1,815	1,771	1,784	1,770	1,750	1,747	1,809.4	1,766.5
standard deviation	131	174	143	157	138	197	138	164	122	161	131.4	167.8
Exports:[b]												
mean	1,016	1,024	1,048	1,009	1,030	1,004	1,038	981	1,048	1,003	1,024.4	1,039.4
standard deviation	138	68	141	91	130	82	134	77	153	94	135.8	83.3
Domestic consumption:[b]												
mean	764	801	778	798	785	801	790	817	793	826	760.3	788.3
standard deviation	46	65	61	69	54	72	53	78	55	61	47.1	65.6
Ending stocks:[b]												
mean	845	352	855	319	889	349	860	356	804	351	826.8	391.1
standard deviation	278	197	237	173	262	141	305	154	284	152	256.1	168.6
Net welfare:[c]												
mean	52,276	51,309	52,023	51,989	51,795	51,889	52,282	51,613	52,433	52,173	52,148.9	52,348.0
standard deviation	4,106	3,547	4,239	4,194	3,781	3,252	3,981	3,345	4,291	4,056	3,970.0	3,907.6
Producers' surplus:[c]												
mean	3,477	2,744	3,696	3,550	3,670	3,527	3,320	3,678	3,575	3,448	3,649.9	3,413.8
standard deviation	1,085	2,129	1,068	2,324	1,012	2,159	1,117	2,377	1,049	2,377	1,021.5	2,273.6
Domestic consumers surplus:												
mean	23,040	22,727	23,220	23,256	23,220	23,256	23,400	23,002	23,580	23,058	22,914.0	23,328.0
standard deviation	520	966	670	614	607	1,101	617	1,106	614	1,002	543.3	960.9

[a] Measured in 1977 dollars per bushel.
[b] Million bushels.
[c] Million dollars.

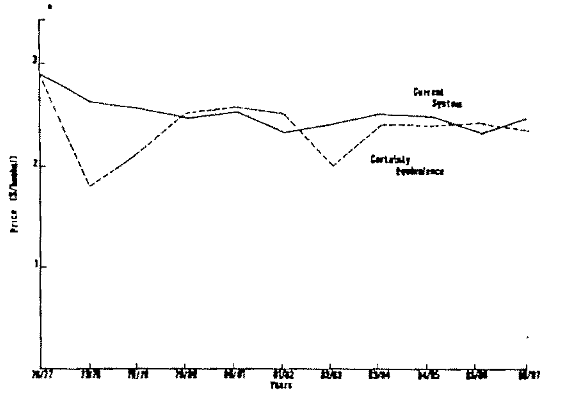


Figure 2. Average prices for 50 simulations

Figure 2 shows the time trends of average price under CS and CE. Initially, price under CE falls below the CS price as existing stocks are disposed, in order to get stocks down to a long-run equilibrium level under CE. After the first three years under a CE rule, price is approximately the same as with CS.

As expected, welfare, as measured by average surplus less storage costs, is higher with CE than with CS; however, the difference amounts to only $199 million per year, or less than $1 per person. Domestic producers are worse off with CE than with CS by about $236 million annually, while domestic consumers gain about $414 million. Foreign consumers' surplus increases by about $70 million under CE as compared to CS.

Interestingly, price variability is greater under CE than CS. Although the CE stock rule differs somewhat from the stabilization scheme considered by Konandreas and Schmitz, it does support their observation that price instability in the wheat sector may be desirable. As noted by Konandreas and Schmitz, this interesting conclusion can be attributed primarily to the fact that the major source of instability in the wheat market arises from the instability of export demand.

Concluding Remarks

There are two major differences between the model presented in this article and other models that have been used to arrive at optimal wheat stock levels. The first difference is that the supply response is incorporated into the model. Other studies have simply viewed production as stochastically varying about a time-trend line.

A second difference is that we have simulated stochastically the use of a first-period, first-order certainty-equivalence decision rule applied to the wheat stock issued, whereas other studies have simply computed the "expected" optimal stock level. This simulation analysis provides important insights into how much the variables in the system might fluctuate under such a decision rule.

While the certainty equivalence rule increases welfare by $199 million per year as compared to the current system, price variability doubled, primarily due to the given initial conditions and to variations in export demand. This supports the observation made by Konandreas and Schmitz that price instability in the wheat sector may be desirable.

Considering the importance of grain stocks to society, it would seem that in addition to more simulation work on buffer stocks proposals, refinements of the optimization model presented here appear in order. One refinement would be to derive an exact expression for surplus rather than a first-order appropriation. A second fruitful extension of the model would be to consider risk either by using surplus in an E-V framework or by putting a probabilistic constraint on the amount of grain that would be available for consumption. A third fruitful pursuit would be to introduce institutional constraints, while a fourth refinement would be to make the model adaptive, whereby the parameters of the system as well as the optimal stock levels could be estimated simultaneously.

[*Received July 1977; revision accepted August 1978.*]

References

Barr, Terry N. "Demand and Price Relationships for the U.S. Wheat Economy." *Wheat Situation*. WS-226, Nov. 1973, pp. 15–25.

Chow, Gregory C. "A Solution to Optimal Control of Linear Systems with Unknown Parameters." *Rev. Econ. Statist.* 57(1975):338–45.

Fletcher, R. "Fortran Subroutines for Minimization by Quasi-Newton Methods." Report R7125 AERE, Harwell, Engl., 1971.

Garst, Gail D., and T. A. Miller. "Impact of the Set-Aside Program on the U.S. Wheat Acreages." *Agr. Econ. Res.* 27(1975):30–37.

Gustafson, Robert L. *Carryover Levels for Grains: A Method for Determining Amounts That Are Optimal Under Specified Conditions*. USDA Tech. Bull. 1178, 1958.

Harberger, A. C. "Three Basic Postulates for Applied Welfare Economics: An Interpretative Essay." *J. Econ. Lit.* 9(1971):785–97.

Houthakker, H. S. "Do We Need A National Food Policy?" *Amer. J. Agr. Econ.* 58(1976):259–69.

Johnson, D. G., and D. Sumner. "An Optimization Approach to Grain Reserves for Developing Countries." *Analysis of Grain Reserves: A Proceedings.* USDA ERS 634, Aug. 1976.

Konandreas, P. A., and A. Schmitz. "Welfare Implications of Grain Price Stabilization: Some Empirical Evidence for the United States." *Amer. J. Agr. Econ.* 60(1978):74–84.

Luttrell, C. B., and R. A. Gilbert. "Crop Yields: Random, Cyclical, or Bunchy?" *Amer. J. Agr. Econ.* 58(1976):520–31.

Malinvaud, E. "First Order Certainty Equivalence." *Econometrica* 37(1969):706–18.

Powell, M. J. D. "An Efficient Method for Finding the Minimum of a Function of Several Variables Without Calculating Derivatives." *Computer J.* 7(1964):155–62.

Prescott, E. C. "The Multi-period Control Problem Under Uncertainty." *Econometrica* 40(1972):1043–58.

Ray, D. E., J. W. Richardson, and G. S. Collins. "A Simulation Analysis of a Reserve Stock Management Policy for Feed Grains and Wheat." *S. J. Agr. Econ.* 7(1975):91–97.

Reutlinger, Shlomo. "Simulation Model for Evaluating Worldwide Buffer Stocks of Wheat." *Amer. J. Agr. Econ.* 58(1976):1–12.

Sharples, J. A., R. L. Walker, and R. W. Slaughter, Jr. *Managing Buffer Stocks to Stabilize Wheat Prices.* USDA Agr. Econ. Rep. 341, July 1976.

Simon, Herbert A. "Dynamic Programming Under Uncertainty With A Quadratic Criterion Function." *Econometrica* 24(1956):74–81.

Takayama, T., and C. L. Liu. "Projection of International Trade in Farm Products: I. Wheat." *Ill. Agr. Econ.* 15(1975):1–7.

Theil, H. "A Note on Certainty Equivalence in Dynamic Planning." *Econometrica* 25(1957):346–49.

Tweeten, L., D. Kalbfleish, and Y. C. Lu. "An Economic Analysis of Carryover Policies for the United States Wheat Industry." Oklahoma Agr. Exp. Sta. Tech. Bull. No. 132, 1971.

Zellner, Arnold. "An Efficiency Method of Estimating Seemingly Unrelated Regression and Tests for Aggregation Bias." *J. Amer. Statist. Assoc.* 62 (1962):348–68.

Appendix A

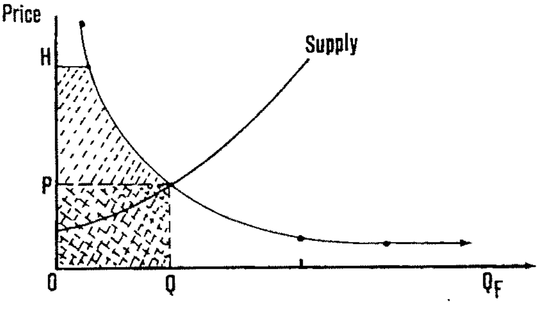
Derivation of Equation (12)

Consider the first component, namely, integration under the domestic demand, equation (3). Rewriting (3) by taking its antilog, gives

$$QF_t = g_0 P^{g_1} t^{g_2}, \tag{3a}$$

where $g_0 = e^{5.0107}$, $g_1 = -0.0126$, $g_2 = 0.2946$.

Figure 1 shows this relation:



Integrating (3a) from P to H and adding the double-shaded rectangle gives

$$\int_P^H QF + PQ \tag{3b}$$

$$= g_0 t^{g_2} \int_P^H P^{g_1} dP + PQ$$

$$= \frac{g_0 t^{g_2}}{g_1 + 1} (H^{g_1+1} - P^{g_1+1}) + g_0 P^{g_1+1} t^{g_2}.$$

Rearranging terms gives the first two components of equation (12). Applying the same procedure on equations (4), (5), and (6) will complete equation (12).

Cattle As a Store of Wealth in Swaziland: Implications for Livestock Development and Overgrazing in Eastern and Southern Africa

M. H. Doran, A. R. C. Low, and R. L. Kemp

The contention that cattle are held as a store of wealth in Swaziland is supported by a regression analysis of slaughter against price and rainfall, and by an examination of the Swazi herd structure. The failure to recognize that cattle directly satisfy both wealth and income motives in traditional societies has led to the implementation of production-oriented livestock development programs, which may worsen the serious overgrazing problem in Swaziland. Observations elsewhere indicate that there are lessons to be learned for livestock development in other overgrazed parts of eastern and southern Africa.

Key words: Africa, cash needs, cattle herd structure, economic development, overgrazing, store of wealth.

The tendency to retain or increase cattle numbers even under adverse environmental conditions is a widespread and characteristic feature of many African societies. The observation that Africa is now perhaps the classic example of a continent suffering from soil erosion caused by overgrazing is a reflection of the nature and extent of the problem (Hodder, p. 42). Governments and aid agencies alike have become alarmed by this serious depletion of the natural resource base and consequently have invested heavily in livestock development programs to alleviate the problem. Many of these programs have, however, been unsuccessful (de Wilde, vol. 2, pp. 111–112) and have failed to make any significant impact on the overgrazing situation.

The problem is particularly acute in parts of eastern and southern Africa. The UNDP/FAO East African Livestock Survey (vol. 2, p. 55) states, for example, that "there are large areas of overgrazing in all three countries (Uganda, Tanzania and Kenya) and destocking is urgently needed in certain districts." This problem is exemplified in Swaziland where widespread soil erosion, bush encroachment, drying up of springs, dam siltation, and low animal productivity have been attributed to overgrazing on the traditional grazing areas (International Bank for Reconstruction and Development, p. 5). The stocking density now stands at an average of 1.9 hectares per livestock unit and the overgrazing problem is recognized as the central issue in livestock development policy.

Most observers have emphasized the significance of the communal grazing systems in explaining the buildup of traditional cattle numbers. In this paper we argue that a less well recognized but important factor is the relationship between the economic motives of generating income and acquiring wealth. In particular, empirical evidence is presented which indicates that cattle slaughterings in Swaziland are inversely related to price and rainfall. This evidence is used, in conjunction with data on Swazi herd characteristics, to support our contention that attitudes towards cattle holding in Swaziland are significantly influenced by the fact that cattle are regarded as a store of wealth. We suggest that the failure to recognize that cattle can satisfy directly

The authors are currently working in the Ministry of Agriculture, Swaziland. M. H. Doran is an agricultural economist supported by the Australian Development Assistance Bureau. A. R. C. Low is a Ministry of Overseas Development (U.K.) agricultural economist, and R. L. Kemp is a computer programmer supported by U.S. AID.

The views expressed in this paper are the authors' alone and do not necessarily reflect those of the agencies respresented or the Government of Swaziland.

both wealth and income motives may have led to counterproductive livestock development programs being implemented in Swaziland. Our arguments also lead us to challenge some of the received wisdom with regard to the factors that will lead to a change of attitude towards cattle holding among traditional graziers in eastern and southern Africa.

The Concept of Cattle as a Store of Wealth

In our following discussion we draw a distinction between wealth and income. Wealth is defined as the accumulation of assets which confer, among other things, security, prestige, and status. It is distinct from income, which provides the means of attaining wealth and supporting current consumption. In many traditional societies, cattle directly perform both functions while in Western societies they are regarded as generators of income through which wealth may be attained. As a source of both wealth and income, cattle provide satisfaction in terms of numbers as well as in terms of cash value. The cash value of animals is important so far as the current consumption needs are concerned; but numbers of animals are often more important than value so far as the security, prestige, and status aspects of wealth are concerned.

Insofar as cattle are regarded as an end in themselves, they cannot be likened to conventional disposable productive assets which are held as long as their capital value in production exceeds their current market value (Jarvis, Nelson and Spreen), and it may be rational to hold cattle beyond the age for income maximization. Recent migration surveys show that Swazis recruited for the South African mines intend to and actually do invest earnings surplus to immediate consumption needs in cattle (de Vletter, Prinz and Rosen Prinz). Examination of the structure of the Swazi herd indicates that these cattle are acquired as a source of wealth (as an end in themselves) and not only as a means of generating further income. Virtually no Swazi cattle are sold for slaughter below the age of three years and the majority of cattle that are marketed are in excess of five years of age (Bishop). Indeed, it is not uncommon to find Swazi cattle (of both sexes) with no teeth at all being offered for sale. This has led to 60% of the Swazi herd being over three years old, as against 45% for European-owned herds (Bishop), and a very low ratio of females to males in this age group (1.4:1).[1] Data over the last decade show that the structure of the Swazi herd has remained constant over time and that, despite a low one-year old survival rate (37.5% of cows), the Swazi herd has been able to grow at the rate of about 3% per annum (Low and Kemp), thus keeping pace with the human population.

The observation that cattle are held as a store of wealth and are only sold to meet specific cash needs has been made elsewhere in eastern and southern Africa (Lele, p. 58; de Wilde, vol. 1, p. 55–56). For example, de Wilde notes that "the widespread reluctance to market cattle regularly stems not so much from an emotional attachment to these animals as from a concept that cattle are a store of wealth or a savings account from which withdrawals are made only for special social or ceremonial occasions or for emergency needs such as payments for education, etc. . . ."

A logical extension of this store of wealth argument includes the following points. (*a*) If cattle must be sold to meet specific cash needs, the minimum number will be sold. (*b*) Factors that increase the market value of cattle will enable the owner to meet his cash needs by selling fewer animals. (*c*) A cattle owner may therefore be interested in improved production and will seek the highest priced markets precisely because this means that he can sell less cattle and thereby maximize his relative wealth. (*d*) When the risk attached to holding wealth in the form of cattle is increased during times of drought, stockowners will become more willing to sell. (*e*) Cattle sales also will tend to increase during times of low rainfall in order to compensate for crop failure.

If our above argument holds, we would expect cattle sales to be related inversely to both cattle price and rainfall. We test this hypothesis with respect to Swazi cattle holding in the regression analysis presented below.

---

[1] In this context it is relevant to mention the land tenure situation in Swaziland. The subsistence sector occupies about 57% of the total land area that is known as Swazi Nation Land; here traditional authority and land tenure systems prevail. Arable land is allocated to individuals on a usufruct basis (about 2–2.5 hectares being cultivated per household on average), while grazing land is communally-owned and used. The remainder of the land area is largely European-owned and managed and classified as Title Deed Land. In 1977 about 14% of Swaziland's cattle population was held on title deed land.

The Relationship between Offtake, Price, and Rainfall

The nature and quality of cattle data in Swaziland is exceptional and perhaps unique in respect of traditional cattle holding. Not only have all slaughterings been comprehensively and consistently recorded over a long period, but similar data is available on herd size. This is significant because, in the context of the store of wealth hypothesis and the overgrazing problem, it is not so much the absolute number of slaughterings that is relevant but the slaughter rate in relation to herd size, i.e., the offtake rate. The fact that total slaughter records are available is also significant because it is important to be sure that the overall offtake is being measured. This is important because it is quite possible to have a positive supply response in a particular market while the overall supply response is negative. In Swaziland we also have the necessary situation where price is exogenously determined and is not dependent on the aggregate supply from the Swazi Nation herd. This situation arises because cattle prices in Swaziland are based on those in South Africa, which country provides an alternative source of supply for cattle buyers in Swaziland. South African cattle prices therefore are used to reflect cattle price movements in Swaziland and these are well documented over the analysis period.

Rainfall data is Swaziland specific and has been taken from two representative stations where consistent records over the analysis period exist.

The Regression Analysis

The multiple linear-regression model is developed using twenty-four annual data points from the period 1950–76.[2] The dependent variable (Y) is the number of cattle slaughtered from the Swazi Nation herd as a proportion of the total herd size. The method used to calculate the percentage offtake is described in the data appendix. The independent variables are real cattle price (X_1) and rainfall (X_2).

Table 1. Data Used in the Regression Analysis

Percentage Offtake	Price (Rands)	Price Adjusted (Rands)	Rainfall (mm)	Year
9.90	79.39	78.26	640.6	1950
12.75	81.16	77.78	602.7	1951
9.96	87.69	81.62	577.6	1952
10.47	96.82	87.65	589.7	1953
9.43	97.66	86.01	680.0	1954
8.60	96.08	82.22	751.5	1955
8.68	99.81	83.01	874.1	1956
8.16	106.37	85.98	780.1	1957
8.82	112.50	88.42	565.4	1958
8.37	110.47	84.47	616.9	1959
9.52	106.58	79.17	677.3	1960
9.87	105.71	76.35	715.4	1961
11.20	102.71	72.11	589.9	1962
12.95	103.96	70.91	600.6	1963
11.36	106.69	70.77	613.0	1964
9.98	147.32	87.20	710.4	1968
8.79	154.32	88.86	609.5	1969
8.78	148.82	83.35	647.0	1970
9.67	148.64	80.83	647.0	1971
9.32	150.35	79.54	721.2	1972
8.34	160.65	82.49	921.2	1973
9.54	189.31	93.09	620.4	1974
8.14	204.35	97.80	737.7	1975
7.54	192.29	90.77	850.3	1976

Real cattle price (X_1) is a simple unweighted average of real cattle price for periods (t), ($t - 1$), where (t) represents a particular year. This is based on the simplifying assumption that cattle marketings are likely to depend on recent past as well as existing price levels. Real prices were calculated by applying a rural cost of living index. Six commodities were included in the index which together amount to about 50% of Swazi rural household expenditure (Flaxen, table 9). The price variable adjusted by the removal of this long-term trend is denoted by ($\hat{X}_1$).

A weighted average of summer rainfall in periods (t) and ($t - 1$) is used for the rainfall variable (X_2), with summer rainfall in period ($t - 1$) being given a weighting twice that of summer rainfall in period (t). Our reasoning

[2] The period 1965–67 is excluded from the analysis. Between 1964 and 1965 there was an exceptional drop in total cattle numbers on Swazi Nation Land following an unusually high death toll in 1964 and a foot and mouth outbreak in 1965. The high mortality in 1964 and 1965 and the restrictions on cattle movements during 1965 therefore probably contributed to the rather low offtake estimate for that year. In 1966 and 1967 the cattle numbers on privately owned land declined substantially, while cattle numbers on Swazi Nation Land declined marginally in 1966 and increased again in 1967. The exceptional drop in cattle numbers held on privately-owned land during 1966 and 1967 can be explained in terms of an unusually high offtake from these herds, due to a combination of an uncertain political climate with impending independence and a sharp increase in cattle prices. Because our procedure for estimating the offtake from cattle on Swazi Nation Land assumes a constant rate of offtake from cattle on privately-owned land (see data appendix), our estimate for 1966 and 1967 is probably relatively high compared with other years. Thus our analysis is based on the two time spans 1950–64 and 1968–76, giving a 24-year observation period.

for double weighting rainfall in period $(t - 1)$ is that we expect stock condition [argument (*d*) above] to be influenced by rainfall in both periods, while food crop supply [argument (*e*) above] will depend only on rainfall in period $(t - 1)$.

A high degree of intercorrelation between time and the unadjusted price variable suggested the need to remove the long-term upward trend in real cattle price and to consider a model with offtake (Y) as the dependent variable and adjusted cattle price ($\hat{X}_1$) and rainfall (X_2) as the independent variables. The resulting estimate for the multiple linear regression equation was

$$\begin{aligned} Y = 23.624 \quad & - 0.119\hat{X}_1 \quad - 0.006X_2 \\ (10.191)^{***} \quad & (-4.384)^{***} \quad (-3.109)^{***}, \\ R^2 = 0.649; \quad & d = 1.923; \quad F = 19.399 \end{aligned}$$

where the values in parentheses are t ratios, *** denotes significance at the 99% level, R^2 is the coefficient of determination, d is the Durbin-Watson statistic, and F, the statistic measuring the significance of the explained sum of squares.

The above results indicate that adjusted price and rainfall account for approximately 65% of the variation in annual offtake. Both variables are highly significant on a t test and both have a negative sign attached to the coefficient. About 40% of the variation in offtake can be attributed to annual price movements away from the long-term trend and 25% to rainfall. The Durbin-Watson statistic suggests that autocorrelation is absent and the F statistic indicates that, for predictive purposes, the R^2 value is significant at the 95% level. Draper and Smith (p. 64) state that, for the regression equation to be regarded as a satisfactory predictor, the observed F ratio should exceed about four times the selected percentage point. The F ratio at the 95% level for our regression equations (having 2 and 21 degrees of freedom) is 3.47.

Thus, although 35% of the variation in offtake remains unexplained, the above regression analysis supports our a priori expectation that offtake from the Swazi Nation herd is inversely related to both price and rainfall.[3] In relation to cattle development and overgrazing, there are significant implications of accepting the hypothesis upon which this expectation was based; namely, that the store of wealth concept strongly influences Swazi behavior with respect to cattle holding.

Implications for Swaziland

In response to the recognition of the seriousness of the overgrazing problem in Swaziland, a UNDP livestock production and extension program was set up in 1973 to coordinate and manage the country's livestock development program. This program, which also has been supported by bilateral aid funding, has concentrated on investment in cattle-fattening ranches, breeding stations, feeding, and pasture improvement trials and improvement in marketing facilities, all of which are designed to improve the quality and or value of stock held. The justification for this emphasis has been based on the implicit assumption that, without doing anything to change the communal grazing system, improved production will induce the stockowner to hold fewer animals because this will enable him to achieve an equivalent or increased income with a reduced herd. However, in common with experience elsewhere in eastern and southern Africa, these programs have failed to alleviate the overgrazing situation. In fact, for the post independence period 1968–77, offtake from the Swazi Nation herd has tended to decline rather than improve. This has resulted in a steadily increasing herd size and has caused grazing pressure to increase accordingly.

The foregoing analysis suggests that the current livestock development programs in Swaziland will, in themselves, tend to exacerbate rather than alleviate the overgrazing problem which is their *raison d'être*. For example, the government-owned and managed fattening ranches, where Swazi cattle owners are encouraged to place their stock prior to slaughter, are said to have achieved success (*a*) because there has been a recent increase in the number of Swazi cattle on these ranches, and (*b*) because it is estimated that on average

[3] The perverse supply response observed in this analysis cannot be equated with periods in the cattle cycles of developed economies where a rising price leads to increased holding of heifers and reduced marketings. This is because (*a*) the response holds over a long period of time (27 years); (*b*) as already noted, there is a strong tendency to retain breeding females in any case so that the potential for retaining additional animals is very limited; and (*c*) the data indicates that the Swazi herd structure remains notably constant.

an animal will gain about $US 50 by going onto a fattening ranch compared to remaining on a Swazi grazing area.

The breeding program aims to upgrade the indigenous Nguni breed through crossing with exotic breeds such as Brahman and Simmentaler. The progeny of such crosses would be expected to mature earlier and obtain higher sale prices at market. If, as we expect, the result of increasing the quality and value of stock will be a reduction in offtake and a consequent exacerbation of the overgrazing situation, any genetic improvement will likely be negated by environmental constraints. Indeed, if, as seems likely, the exotic cross animals suffer more heavily from environmental stress than the Nguni, they will tend to be culled out in preference to the Nguni and the genetic improvement will be lost quickly.

Clearly, if offtake is to be increased, the production-oriented approach that has been followed in Swaziland is not enough by itself. It also will be necessary either to implement measures that will induce stockowners to sell more cattle or, alternatively, to enforce control of cattle numbers.

In Swaziland stockowners may be induced to sell more cattle by increasing farmers' cash requirements or by adopting measures that make cattle less attractive as a wealth store. It is generally believed that, over time and through the development process, the need for cash will increase and the relative importance of cattle as a store of wealth will decline. There is, however, little evidence to indicate that the relative importance of cattle for the traditional Swazi farmer has declined over the last twenty-seven years. Although the requirement for cash undoubtedly has increased, other opportunities for earning cash have expanded (e.g., cotton and tobacco production and employment on South African mines [Doran]) and real cattle prices have increased. Moreover, cattle still appear to represent the most accessible and reliable vehicle for the accumulation of wealth, because the farmer has no individual title to land or the structures thereon.

At the present time in Swaziland, it is probably unrealistic to think in terms of decreasing the desire to hold cattle as a wealth store through changes in land tenure. Thus, it would appear that it will be necessary to enforce control of cattle numbers if the overgrazing situation is to be alleviated.

Implications in General

In general, we would expect persuasive measures to have a rather limited impact on offtake rates where there exist (*a*) expanding opportunities for earning cash elsewhere, and/or (*b*) a lack of alternative sources for investing wealth. In this latter connection, the land tenure question probably plays an important role. We would argue, for instance, that de Wilde (vol. 1, p. 56) probably has misinterpreted evidence for factors that he assumes will change attitudes of stockholders towards cattle holding in East Africa. In his discussion of the Kikuyu, Baringo, the Central Nyanzan tribes of Kenya, and the Sukuma of Tanzania, he argues that increased cash-earning opportunities (through cash cropping) have induced a change in attitude to cattle holding so far as the Kikuyu are concerned. Under similar circumstances, however, the Baringo, Central Nyanzan, and Sukuma people showed no tendency to reduce herd size. At the time that this observation was made, the Kikuyu had obtained individual ownership rights to agricultural land, whereas the other groups had no such rights, even though, in some cases, moves were afoot to alter the systems of land tenure. For the Kikuyu, it would therefore seem that land had replaced cattle as the desired symbol and store of wealth whereas, for the other tribes, this shift had not been possible.

From our experience in Swaziland, we would suggest that the important point in respect of attitudes to cattle holding often may not be connected so much with income-earning opportunities as with the opportunity for holding and accumulating wealth in other acceptable forms. An increase in income-earning potential without a corresponding increase in acceptable alternative investment opportunities may, in fact, exacerbate the overgrazing problem because surplus cash will tend to be invested in cattle. This appears to have happened, for example, in Uganda (Belshaw), Tanzania (de Wilde, vol. 2, p. 423), and Malawi (ECA/FAO, p. 121) as well as Swaziland.

Given the importance attached to cattle in most eastern and southern African societies, grazing control schemes generally are politically unpopular (de Wilde, vol. 2, pp. 179–81; International Bureau for Animal Resources). It is not surprising, then, that independent

governments have preferred to avoid political decisions involving grazing control measures. Furthermore, in areas already overgrazed, control measures generally will involve an element of destocking to bring the number down to the carrying capacity of the area. Clearly, a fair allocation of grazing permits must take account of the size and structure of individual herds. In addition it will be necessary to ensure that surplus stock are marketed and not transferred to uncontrolled grazing land.

These problems indicate a need for detailed preparatory work to establish carrying capacities, systems of permit allocations, and disposal mechanisms. Plans will need to be derived for individual grazing areas and they will need to be flexible enough to take account of climate and other changes through time. We would argue that the above are, in many instances, the types of problems upon which livestock development planners and technicians in eastern and southern Africa should be concentrating their attention.

[Received November 1977; revision accepted August 1978.]

References

Belshaw, D. R. G. "The Level of Incentives: A Factor Limiting Agricultural Production in Uganda." Paper presented at annual conference, Uganda Agricultural Association, 1963.

Bishop, Dwight R. *Livestock Marketing in Swaziland.* Ministry of Agriculture, Swaziland, 1974.

Doran, M. H. "Swaziland Labour Migration—Some Implications for a National Development Strategy." Int. Labor Org. mimeographed work. pap. (WEP-2-26/WP 12), Geneva, Aug. 1977.

Draper, N. R., and H. Smith. *Applied Regression Analysis.* New York: John Wiley & Sons, 1966.

Flaxen, D. W. "The Swaziland Rural Homestead Survey." Mbabane, Swaziland: Central Statistics Office, mimeographed, 1972.

Hodder, B. W. *Economic Development in the Tropics.* London: Methuen & Co., 1968.

International Bank for Reconstruction and Development (IBRD). "Swaziland Rural Development Project Appraisal Report." Washington, D.C., Jan. 1977.

International Bureau for Animal Resources. "Plan to Boost Cattle-Ranching by Overhauling Traditional Land Tenure in Botswana." Nairobi, Kenya: Info. Leaflet, vol. 25, no. 37, Oct. 1977.

Jarvis, Lovell S. "Cattle As Capital Goods and Ranchers As Portfolio Managers: An Application to the Argentine Cattle Sector." *J. Polit. Econ.* 82(1974):489–520.

Lele, U. *The Design of Rural Development: Lessons from Africa.* Baltimore, Md.: Johns Hopkins University Press, 1975.

Low, A. R. C., and R. L. Kemp. "Destocking Dynamics: The Implications of a Swaziland Example." *Oxford Agrarian Stud.* 6(1977):26–43.

Nelson, Glenn, and Thomas Spreen. "Monthly Steer and Heifer Supply." *Amer. J. Agr. Econ.* 60(1978):117–25.

Prinz, F. A., and B. D. Rosen-Prinz. "Migrant Labour and Rural Homesteads: An Investigation into the Sociological Dimensions of the Migrant Labour System in Swaziland." Geneva, Switz.: Int. Labor Org. Mimeographed Work. Pap. WEP-2-26/WP31, Sept. 1978.

United Nations Development Program, Food and Agriculture Organization (UNDP/FAO). "East African Livestock Survey." Rome: FA/SF:21 REG, 1967.

United Nations, Food and Agriculture Organization, Department of Economic Affairs (ECA/FAO). *African Livestock Development Study, Southern and Central Africa,* vol. 2, part 1. Addis Ababa, 1973.

de Vletter, Fion. "Migrant Labour in Swaziland: Characteristics, Attitudes and Policy Implications." Geneva, Switz.: Int. Labor Org. Mimeographed Work Pap. WEP-2-26/WP 22, Feb. 1978.

de Wilde, J. C. *Experiences with Agricultural Development in Tropical Africa,* vol. 1, 2. Baltimore, Md.: Johns Hopkins University Press, 1967.

Appendix

Estimation of Swazi Herd Offtake Rates

The veterinary department carries out an annual cattle census which records the size of the herds on Swazi Nation Land and on privately-owned land.

All cattle in the country are dipped regularly (once weekly in summer and biweekly in winter). At each diptank a register of herds by owner is maintained. At each dipping the owner must account for any additions to or losses from his herd. In this way a record of all slaughterings is obtained. This total slaughtering figure includes animals imported into the country for slaughter but excludes stock exported for slaughter in the Republic of South Africa.

The following simple formula is used to estimate the annual offtake percentage from the herd on Swazi Nation Land.

$$\frac{TS + (EXP - IMP) - 14\%\ POLC}{SNLC} \times 100,$$

where: TS is total slaughterings, EXP is number exported for slaughter, IMP is number imported for slaughter, $POLC$ is privately owned land cattle, and $SNLC$ is Swazi Nation Land cattle.

Thus the total slaughterings data is adjusted to account for exports and imports giving a slaughter figure from the total cattle population in the country. From this is subtracted a constant proportion of the herd on privately-

owned land. The resulting slaughter figure represents the offtake from the herd on Swazi Nation Land and is expressed as a percentage of the total number of cattle held on traditional grazing areas.

The assumed constant rate of offtake from cattle on privately-owned land is based on the argument that relative supply response to price is likely to be inelastic. Farmers with breeding herds will tend to maintain a constant herd size irrespective of short-term price movements, with the annual offtake being determined largely by technical parameters such as calving percentage and replacement requirements.

Agricultural Development and Land Tenancy in a Peasant Economy: A Theoretical and Empirical Analysis

Pranab K. Bardhan

In this paper we have a two-season model of agricultural production in a peasant economy, with labor unemployment in the lean season, land rationing at a conventionally fixed crop share by a monopolistic landlord who is also the financier of consumption credit for the sharecropper families. We then work out hypotheses about the relation of the equilibrium percentage of area under tenancy with land quality factors, labor-intensity of crops, extent of unemployment, interest rates, weather uncertainty, etc. Most of the hypotheses are confirmed by interstate cross-section evidence from India in early 1950s.

Key words: consumption credit, India, land rationing, lean season, peak season, sharecropping.

Does agricultural development weaken the institution of land tenancy in a peasant economy? The evidence in India seems to give a conflicting picture. The time-series evidence suggests a decline in the incidence of tenancy along with agricultural progress; but interregional cross-sectional data seem to suggest that the agriculturally better-off regions have a larger proportion of area under tenancy. A major purpose of this paper is to provide an analytical focus on this question.

The existing theoretical literature on agricultural tenancy is not of much help in understanding this problem. Most of the literature deals with normative questions, like the one related to efficiency of sharecropping compared to other forms of land institutions. (For a brief summary of the literature up to 1950, see Johnson; since then, Georgescu-Roegen, Cheung, Bardhan and Srinivasan, Stiglitz, Newbery, and Bell and Zusman have contributed to the theoretical literature.) The literature on an analysis of the economic factors that may explain variations in the incidence of tenancy in general and sharecropping in particular is much smaller. Day has related the decline of sharecropping in the Mississippi Delta since the 1930s to the large-scale introduction of labor-saving technical progress. Bray discusses regional variations in the incidence of tenancy in the United States and relates them to productivity differentials. Cheung has discussed the impact of production risk and transaction costs on forms of tenancy in pre-Communist China. Reid has assessed the impact of similar factors on the rise of agricultural tenancy in postbellum American South. Rao has pointed to the importance of entrepreneurial decision-making factors in the face of uncertainty in determining the specific form of tenancy. Raj has tried to relate regional variations in tenancy to factors like different labor requirements for different crop patterns and the risk of default of rent by the tenant.

In an earlier paper by Bardhan and Srinivasan, we tried to find out, theoretically as well as empirically in relation to Indian agriculture, the influence of the level of the agricultural wage rate and that of land-augmenting technical progress on the incidence of sharecropping. But the model in that paper was one of a simple competitive equilibrium in the land market. Like most of the literature on the subject, it explicitly ignored imperfections in the land market and the complex interlinkage between them and imperfections in labor and credit markets. In the present paper we include some of these imperfections into a model of the peasant economy and then try to use this model to generate hypotheses about

---

Pranab K. Bardhan is a professor in the Department of Economics, University of California, Berkeley.

the impact of agricultural development on the incidence of tenancy. These hypotheses are then related to empirical data on Indian agriculture, so as to throw some light on the question posed in the first paragraph of this paper.

The plan of the paper is as follows: In the second section we describe the basic theoretical model. Next we derive a number of comparative-static propositions about variations in the extent of tenancy with variations in different parameters. Then we empirically test these comparative-static propositions with cross-sectional data from Indian agriculture. Finally, we comment briefly on the introduction of production uncertainty in the model.

The Model

There are two seasons in the crop cycle: season one for land preparation, sowing, interculture, etc., and season two for harvesting. Land and labor (and, in one variant of the model, fertilizers) produce "saplings" at the end of season one; "saplings" and labor produce crop output at the end of season two. There is, thus, complementarity in production in the two seasons. The seasonal distinction is also important from the point of view of the conditions in the various input markets. Take, for example, the labor market. Season one also happens to be in part what is known as a "lean" season. In this season the market wage rate does not clear the labor market and there is unemployment. On the other hand, in season two, which coincides with the "peak" season, there is full employment and the wage rate is competitively determined.

The seasonal distinction is also important because of the nature of credit market. The landless tenant is dependent on the landlord for credit to finance his subsistence consumption in the lean season and he pays back the loan along with interest at the end of the harvest. Because the interest rates are usually very high, it matters a great deal how long one has to wait until income accrues. For example, the landless tenant knows that as a wage laborer (provided he is lucky to get employment) he can get some wage income immediately in season one, whereas as a tenant he has to wait until the crop is harvested in season two. The landlord also notices that if he increases his hiring of labor in season one, he thereby reduces the credit needs of his borrowers.

In the land (lease) market we assume that there is a conventional[1] (commonly 50:50) crop share; and at that rental rate, the landlord decides how much land to lease out to sharecroppers. The latter do not participate in this decision. This reflects some monopoly power on the part of the landlord, which is not unrealistic in the general Indian context of acute tenurial insecurity, heavy demographic pressure on land, and a highly skewed distribution in its ownership. (Most of the tenancy contracts are oral and in many areas the tenants can be evicted easily by the landlord; if anything, as a result of likely underreporting, they underestimate the actual extent of tenurial insecurity.) Our model thus envisages a situation of excess demand in the land-lease market at the conventional rental share, with land rationing by the monopolistic landlord.

Suppose $Q(BA, L)$ is the number of "saplings" produced at the end of season one on the landlord's farm. In this production he uses L amount of labor (entirely hired) and A amount of land acreage. B is a land-augmenting improvement factor. In the traditional agriculture of densely populated peasant economies, most important forms of technical progress tend to increase the effective supply of land. (See, for example, Ishikawa and Hayami and Ruttan.) At any rate, the Indian data that we use in our subsequent empirical analysis relates mostly to a period when use of labor-saving machinery in agriculture was insignificant. Even in recent years the chemical-biological breakthrough in production with the use of high-yielding variety of seeds, chemical fertilizers, pesticides, etc.—the so-called green revolution—has been largely land-augmenting in nature. The total area owned by the landlord, $\bar{A}$, is given, and out of this he leases out A_t, and $A(=\bar{A} - A_t)$ is what remains with him for cultivation. $Q_t(BA_t, L_t)$ is, similarly, the number of "saplings" produced at the end of season one on the sharecropping tenant's farm, and L_t is the amount of labor the sharecropper uses on his farm in season one. For simplification we assume that the "saplings" production functions Q and Q_t are similar and

[1] 50:50 crop share has been a remarkably unchanging phenomenon in land rental markets across regions and over centuries. In very recent years in India some changes in this rental share have been observed, particularly with the progress of cost sharing. We have not introduced cost sharing in our model, particularly because for the period to which our data refer cost sharing was not very significant.

both display constant returns to scale with changes in effective acreage and labor.

Notice that we have used the same land-augmenting factor B in both the production functions. To the extent the land improvement term refers to natural fertility factors, we are assuming that the land on both the landlord and tenant farms is homogeneous with respect to soil rating, rainfall, evapo-transpiration rates, etc. To the extent the land improvement factor is due to irrigation, in most parts of India the major source of effective irrigation is public canals. Assuming the same B implies that both the tenant and the landlord have equal access to canal irrigation. To the extent the land-augmenting technical progress is due to adoption of high-yielding varieties of seeds, assuming the same B implies that both the tenant and the landlord have equal access to the seeds and to the requisite knowledge. We shall comment on the cases where there are landlord-tenant differences in the land-augmenting improvement factor due to unequal access either to irrigation facilities (the insecure tenant may be uninterested in digging field channels or investing in tubewells) or to new varieties (due to, say, market imperfections, particularly in credit).

With the use of harvesting labor, "saplings" produce output, say, in fixed proportions. Let us suppose one unit of "saplings" ends up in one unit of crop harvest. We can now write the landlord's income at the end of the crop cycle as

$$(1) \quad Y = [1 - \beta w_2]Q(BA, L) + rQ_t(BA_t, L_t) + iC - (1 + i)w_1L,$$

where r is the conventional cropshare, i the interest rate (per season), w_1 is the given wage rate in season one, and w_2 is the competitively determined wage rate in season two, β is the amount of harvesting labor used per unit of "saplings," and C is the given subsistence consumption of the tenant family that the landlord finances with credit. The landlord has, thus, three sources of income: rental income from leased-out land, income from self-operated land net of wages paid in season one and two, and interest income. There is only one final commodity in this model and all rental, wage, or interest payments are in terms of this commodity.

The tenant's income at the end of the crop cycle is given by

$$(2) \quad Y_t = (1 - r)Q_t(BA_t, L_t) + (1 + i)w_1\mu(1 - L_t) + w_2(1 - \beta Q_t) - iC.$$

As we have indicated before, in lean season one the wage rate w_1 does not clear the labor market. In that season the tenant is prepared to supply $(1 - L_t)$ amount of wage labor but expects only a fraction of it, μ, to get wage employment on the landlord farm, and the rest is unemployed. In both seasons the total number of potential workers in the tenant family is given at unity. It is assumed for simplification that the tenant does not own any land of his own.[2]

There is some dispute in the literature about the landlord's control over the tenant's use of labor on the latter's farm. Cheung assumes that the landlord decides on the labor use on the tenant farm (his result of efficiency of sharecropping depends on this assumption). But, even when the landlord has some monopoly power, it is difficult for him to enforce the quantity and quality of labor used on the tenant farm without incurring heavy supervision costs which the sharecropping system is supposed to economize. We, therefore, assume that the landlord cannot control the tenant's use of labor intensity per acre, a_t. He maximizes Y with respect to his decision variables, A_t, and L (keeping in mind that $L_t = \frac{BA_t}{a_t}$ where he can control A_t, but not a_t) and gets the necesssary conditions of interior maximum,

$$(3) \quad r\frac{q_t}{a_t}(a_t) - [1 - \beta w_2]q'(a) = 0,$$

and

$$(4) \quad [1 - \beta w_2][q(a) - q'(a)a] - (1 + i)w_1 = 0,$$

where q and q_t are the average productivities of labor in season one and $a\left(= \frac{BA}{L}\right)$ and $a_t\left(= \frac{BA_t}{L_t}\right)$ are the effective land-labor ratios in season one on the landlord and tenant farms, respectively. If marginal productivity of each factor is diminishing, the Jacobian, J,

[2] This ignores the problem posed by the landlord's often preferring a landed tenant to a landless one. Raj relates this to the risk of default of rent by small landless tenants. But in a situation where sharecropping is the predominant form of tenancy and/or the landlord has monopolistic power, there are many ways in which the landlord can exact his full rent at least over the long or even the medium run from his landless tenant. What may be more important is that the landed tenant may have access to more entrepreneurial and capital resources than the landless tenant.

Another frequent constraint on the landless tenant leasing in land, ignored in our model, is ownership of bullocks for cultivation. This aspect has been emphasized by Bell and is particularly important when the market for hiring bullock service is limited.

of equations (3) and (4) is positive and the second-order conditions of maximization are satisfied.

From (3) and (4),

$$(5)\quad \frac{\partial A_t}{\partial w_2} = -\frac{\beta}{J}[1-\beta w_2]\,\frac{a}{L}\,q(a)q''(a) > 0,$$

and

$$(6)\quad \frac{\partial L}{\partial w_2} = \left[\frac{\beta}{J}\right]\left[-r\frac{(q_t - q'_t a_t)}{a_t A_t}[q(a) - q'(a)a] + [1-\beta w_2]\frac{a}{A}\,q(a)q''(a)\right] < 0.$$

As expected, a higher harvesting wage, other things remaining the same, makes the landlord hire fewer laborers in "saplings" production and induces him to lease out more land.

The tenant maximizes his income Y_t with respect to his only decision variable L_t and gets as a necessary condition of interior maximum,

$$(7)\quad \mu(1+i)w_1 - (1 - r - \beta w_2)[q_t(a_t) - q'_t(a_t)a_t] = 0.$$

Note that in the interior, $(1 - r - \beta w_2)$ has to be positive (which is generally the case with r at 50%, and βw_2—the share of harvest paid as wages—is usually not more than 10%). This implies in equation (3) that

$$(8)\quad \frac{q_t}{a_t}(a_t) > q'(a).$$

Equation (8) is consistent with $a_t \gtreqless a$, even if production functions Q and Q_t are similar. In this model the standard Marshallian effects tend to raise a_t above a, while the effect of unemployment tends to lower it.

In peak season two there is full employment, so that

$$(9)\quad \beta Q(BA, L) = 1 - \beta Q_t(BA_t, L_t),$$

where the left-hand side represents the demand for wage labor for harvesting on the landlord's farm[3] and the right-hand side, the corresponding supply. Given the equations (3), (4), and (7), equation (9) determines the equilibrium harvesting wage rate w_2. Using (5) and (6) in (9), we can see that the demand for wage labor for harvesting is a declining function of the harvesting wage, given L_t. Also, L_t is a declining function of w_2 from equation (7). But the supply of wage labor for harvesting—the right-hand side of (9)—may or may not be an increasing function of the wage rate, w_2. This is because a higher w_2, by inducing more leasing out on the part of the landlord, increases tenant output of "saplings" and therefore labor required for harvesting them on the tenant farm. If we want the standard Walrasian stability (and uniqueness) condition to be satisfied, we need

$$(10)\quad K = \frac{\partial[Q + Q_t]}{\partial w_2} = B\frac{\partial A_t}{\partial w_2}(q'_t - q') + (q - q'a)\frac{\partial L}{\partial w_2} + (q_t - q'_t a_t)\frac{\partial L_t}{\partial w_2} < 0.$$

But, of the three terms on the right-hand side of (10), the last two are negative while the first is uncertain. The first term is nonpositive, when production functions on the landlord and tenant farms are similar, if $a_t \geqq a$, i.e., the labor intensity on the landlord farm is not less than that on the tenant farm. Because the other terms are negative, this factor-intensity condition is sufficient, but by no means necessary, for K to be negative in (10).

Comparative-Statics

Given the basic model, let us now work out some comparative-static propositions. Let us first carry out a parametric variation in the land-augmenting improvement factor, B.

From (3) and (4), after simplification,

$$(12)\quad \frac{\partial A_t}{\partial B} = -\frac{A_t}{B},$$

and

$$(13)\quad \frac{\partial L}{\partial B} = \frac{\bar{A}}{a}.$$

Using (12) and (13) in the equilibrium condition (9),

[3] We assume that the landlord is a monopolist in the land-lease market but not in the labor market where the harvesting wage is determined. The landlord recognizes himself as only one of the many demanders of labor in the harvesting season and we assume that demand for labor by others (say, by nonleasing farmers, nonagricultural employers, etc.) is not very sensitive to changes in w_2, so that it is a constant in the wage-determination equation and, without loss of generality, we take that constant to be zero. The need for making this assumption explicit was pointed out to me by John Flemming.

$$(14)\quad \frac{dw_2}{dB} = -\frac{1}{K}\left[\frac{q}{a}\bar{A} + 2\frac{A_t}{a_t}(q_t - q'_t a_t)\right] > 0.$$

So, an increase in the land-augmenting improvement factor increases the equilibrium harvesting wage rate. Now,

$$(15)\quad \frac{dA_t}{dB} = \frac{\partial A_t}{\partial B} + \frac{\partial A_t}{\partial w_2}\frac{dw_2}{dB}.$$

Equation (15) indicates the two conflicting influences of land-augmenting, agricultural progress on the extent of land leased out by the landlord: $\frac{\partial A_t}{\partial B}$ being negative, or self-cultivation being more profitable, the landlord tends to lease out less at constant w_2, the harvesting wage rate. The harvesting wage rate does not remain constant; it actually goes up, which induces the landlord to self-cultivate less and lease out more. Using (5), (12), and (14), we can see that the latter effect will dominate and $\frac{dA_t}{dB}$ is positive under the sufficient conditions that the elasticity of substitution does not exceed unity and that the labor elasticity of output on the sharecropper's farm is small enough, which is not unrealistic to assume for a peasant economy. (For example, if production functions are Cobb-Douglas, rental share is 50%, and share of harvest paid as wages does not exceed 25%, any value of the labor elasticity of output of "saplings" less than or equal to 0.75 is sufficient for our result. In the development literature, the labor elasticity of output in peasant agriculture (in the lean season) is often put at a much lower value, sometimes even at zero.) In that case land-augmenting improvement in our model leads to a higher percentage of area under tenancy.

These results hold when the land improvement parameter, B, is the same for both landlord and tenant farms. But, as we have indicated in the preceding section, the landlord and the tenant may have unequal access (or incentive) to land improvement. This will tend to modify our result. Take the extreme case when B appears as before in the landlord's production function $Q(BA, L)$, but disappears altogether from $Q_t(A_t, L_t)$, the tenant's production function. Reworking equations (3) through (15), we find that even in this case $\frac{dA_t}{dB}$ is positive, if the elasticities of substitution are very small.

Suppose, however, that land-augmenting technical progress (say, in the form of high-yielding varieties of seeds) requires the purchase of some current inputs or services (like chemical fertilizers, water from tubewells, or rental of the service of a pumpset) and the market for the latter is imperfect (maybe because the landlord has better connections and access to the government-subsidized distribution of fertilizers or because the landless tenant has fewer channels of cheap credit open to him with which to buy these inputs) so that the landlord has differential advantage over the tenant. In this case it is easy to prove that the larger is the degree of imperfection in the market for these inputs, the lower is the percentage of area under tenancy, other things remaining the same (unless the landlord decides to cost-share or buy the inputs himself and sell them to the tenant).

Now let us take up the case where there is a parametric variation in β, the harvesting labor coefficient. From (3), (4), and (7),

$$(16)\quad \frac{\partial A_t}{\partial \beta} = \frac{\partial A_t}{\partial w_2}\frac{w_2}{\beta} > 0,$$

$$(17)\quad \frac{\partial L}{\partial \beta} = \frac{\partial L}{\partial w_2}\frac{w_2}{\beta} < 0, \text{ and}$$

$$(18)\quad \frac{\partial L_t}{\partial \beta} = \frac{\partial L_t}{\partial w_2}\frac{w_2}{\beta} < 0.$$

From the equilibrium condition (9),

$$(19)\quad \frac{dw_2}{d\beta} = -\left[B(q'_t - q')\frac{\partial A_t}{\partial \beta} + (q - q'a)\frac{\partial L}{\partial \beta} + \frac{(Q + Q_t)}{\beta} + (q_t - q'_t a_t)\frac{\partial L_t}{\partial \beta}\right]\Big/K.$$

Using (16), (17), (18), and (19) and that K is negative as a stability condition,

$$(20)\quad \frac{dA_t}{d\beta} = \frac{\partial A_t}{\partial \beta} + \frac{\partial A_t}{\partial w_2}\cdot\frac{dw_2}{d\beta} = -\frac{\partial A_t}{\partial w_2}\frac{(Q + Q_t)}{\beta K} > 0.$$

Equation (20) implies that an increase in the harvesting labor coefficient β increases the percentage of area under tenancy in equilibrium, other things remaining the same. This

suggests that tenancy would be larger in areas where the crop is more labor-intensive. Alternatively, if there is a labor-saving technical change reducing the harvesting labor requirement per unit of output, tenancy will tend to decline. (This is consistent with the observation by Day that large-scale mechanization substituting for hand-picking of corn and cotton contributed to a rapid decline in sharecropping in the Mississippi Delta.)

Now, suppose there is a parametric variation in the interest rate, i; from (3) and (4) we get

$$(21)\quad \frac{\partial A_t}{\partial i} = -\frac{w_1}{J}[1 - \beta w_2]q''(a)\frac{a}{L} > 0,$$

and

$$(22)\quad \frac{\partial L}{\partial i} = \frac{w_1\left[(1 - \beta w_2)q''\frac{a}{A} + \frac{r(q_t - q'_t a_t)}{A_t a_t}\right]}{J} < 0.$$

From (7),

$$(23)\quad \frac{\partial L_t}{\partial i} = \frac{\mu w_1 L_t}{q''_t(a_t)^2(1 - r - \beta w_2)} < 0.$$

From the equilibrium condition (9), we get

$$(24)\quad \frac{dw_2}{di} = -\frac{1}{K}\left[(q - q'a)\frac{\partial L}{\partial i} + B\frac{\partial A_t}{\partial i}(q'_t - q') + (q_t - q'_t a_t)\frac{\partial L_t}{\partial i}\right].$$

Now, from (5), (6), (21), (22), (23), and (24) we can check that

$$(25)\quad \frac{dA_t}{di} = \frac{\partial A_t}{\partial i} + \frac{\partial A_t}{\partial w_2}\ \frac{dw_2}{di} < 0.$$

In (25) we can see that there are two conflicting influences of a rise in the interest rate on tenancy: $\frac{\partial A_t}{\partial i}$ being positive, a higher interest rate induces the landlord to lease out more at a given harvesting wage rate; but a higher interest rate partly tends to depress the harvesting wage rate, making self-cultivation more profitable for the landlord. The net result is in general uncertain, but if the labor elasticity of output of "saplings" is sufficiently small, the second effect dominates and $\frac{dA_t}{di}$ is negative: a higher interest rate implies a lower equilibrium percentage of area under tenancy.

Similarly, if the parametric variation is in μ—the objective probability of getting wage employment for the tenant in the lean season—it is easy to see from (3) and (4) that $\frac{\partial A_t}{\partial \mu} = \frac{\partial L}{\partial \mu} = 0$, that $\frac{\partial L_t}{\partial \mu}$ is negative, and that $\frac{dA_t}{d\mu}$ also is negative. In other words, the larger the extent of unemployment in the lean season, the higher the incidence of tenancy.

Results

Summarizing the comparative-static propositions of the preceding section, we have shown under the conditions in our model that (*a*) the percentage of area under tenancy will be higher in areas where the land improvement factor is larger (i.e., soil fertility, rainfall, irrigation, etc., is better); (*b*) the larger the degree of imperfection in the market for inputs complementary with high-yielding variety of seeds (or in the market for credit with which to buy these inputs), the lower the percentage of area under tenancy; (*c*) the larger the labor-intensity of the crop harvested, the higher the percentage of area under tenancy (alternatively, if there is a labor-saving technical change reducing the harvesting labor requirement—say, through the introduction of harvesters—tenancy will decline); (*d*) the percentage of area under tenancy will be smaller in areas with higher interest rates on credit; and (*e*) the larger the extent of unemployment facing landless households, the higher the extent of tenancy.

In the appendix table we have put together some interstate cross-section data for India in early 1950s which we are going to use in testing some of the propositions above.[4] In the table, X_1 refers to the percentage of cultivated area under tenancy in nineteen states in 1953–54. X_2 refers to the percentage of cropped area irrigated; X_3 to the percentage of area under rice, *ragi*, barley, and jute (the most labor-intensive crops in the Indian cropping pattern) to the total cropped area;[5] X_4, amount

[4] Similar data are available for one or two more recent years, but meanwhile land legislation intended to protect tenants has resulted in large-scale eviction and also driven tenancy underground, so that the subsequent tenancy data are likely to be much less reliable.

[5] The National Sample Survey Report no. 170 gives data on human labor days utilized per acre for a number of crops. Except for sugarcane (which being a "perennial" crop is on a different

borrowed by small cultivators for household expenses to total borrowing by the same cultivators; X_5, the proportion of total leased-in area from which the tenant, under the existing contract, could be evicted at will by the landlord; and X_6, the total number of unemployed days (for males) in agricultural labor households.

The variable X_2 may serve as a crude proxy for regional differences in land improvement due to differences in irrigation. One is assuming here that in efficiency units, a piece of irrigated land may be regarded as a multiple of a piece of unirrigated land of the same acreage (ignoring, for lack of data, that the same value of X_2 may have different land improvement effects depending on the effectiveness of the particular types of irrigation). According to our proposition (*a*), we should expect a positive relationship between X_1 and X_2. According to our propositions (*c*) and (*e*), we again should expect a positive relationship between X_1 and X_3, and between X_1 and X_6.

For testing proposition (*d*), we need interest rates and reliable data which are extremely scarce. Instead, we have relied on a very indirect proxy, X_4, which indicates the extent of dependence of small cultivators on borrowing for household consumption. The presumption is that the larger is this dependence, the lower their elasticity of demand for credit and the higher the effective interest rate that the moneylender will charge them. If this is the case we should expect a negative relationship between X_1 and X_4.

One index of the monopoly power of the landlord over the tenant in the form of the threat of tenurial insecurity is X_5. In our model there is no parameter that may reflect this index. (It is built into the model in the sense that the landlord alone decides about how much land to allocate to the sharecropper at the conventionally given 50:50 crop share and the latter passively accepts it.) If the landlord exerts this monopoly power to make the tenant also enter into some labor-tying arrangement (to ensure a smooth supply of labor on the landlord farm in the peak season), this may have a wage-depressing effect leading to a decline in the extent of land leased out. In that case we should expect a negative relationship between X_1 and X_5.

On the basis of the data in the appendix table, we have the following least squares estimate for a linear equation (with standard errors in parenthesis):

$$
\begin{aligned}
X_1 = {} & \underset{(10.631)}{14.681} + \underset{(0.161)}{0.434}\, X_2 + \underset{(0.076)}{0.179}\, X_3 \\
& - \underset{(0.154)}{0.165}\, X_4 - \underset{(0.118)}{0.268}\, X_5 + \underset{(0.047)}{0.133}\, X_6,
\end{aligned}
$$

$$R^2 = 0.775 \quad \text{and} \quad F = 6.875$$

The coefficients of all the independent variables (except X_4) are significant at a less-than-5% level and have the expected signs. X_4 has the expected negative sign, but is not statistically significant. The F-value for the equation is significant at a less-than-1% level.

Let us comment more on our finding that there is a significant positive relationship between the land improvement factor and tenancy.[6] This is on the basis of interregional cross-section data, indicating that better irrigated areas have a larger incidence of tenancy. As we mentioned in the beginning of this paper, the intertemporal evidence in Indian agriculture in recent years seems to point to the opposite direction, that over the last two decades (a period in which any index of irrigation or of land improvement shows a significant rise) the percentage of cultivated area under tenancy declined substantially. (This is evident when one compares the results of the National Sample Survey of Land Holdings for 1970–71 with those for 1960–61 and 1953–54.) The primary reason for this decline is related to the impact of protective tenancy legislation in most states in India or outright abolition of tenancy in other states. It has led to large-scale eviction of tenants by landlords. This is a factor obviously not incorporated into our model in the preceding sections.

In our model the land improvement factor tends to increase the extent of tenancy mainly by raising the wage rate and thereby cancelling the enhanced profitability of self-cultivation. It is possible that in areas of recent agricultural progress in India significant in-migration of

footing altogether), rice, *ragi*, barley and jute are by far the most labor-intensive crops; human labor days used per acre on these crops are substantially larger than (sometimes more than twice) those for other crops like wheat, cotton, *jowar*, *bajra*, pulses, and oilseeds.

[6] This positive relation can be confirmed in other contexts as well. We have checked from the National Sample Survey interstate land holdings data for 1960–61 that the correlation between the percentage of area under tenancy and that under irrigation is 0.638 (for 1970–71 data it is 0.663). Sharma has found in the 1961 Census data for 301 districts in India that the correlation between the percentage of area cultivated by a landless tenant to total area and the average annual rainfall in the district (for 1959–62) is significant at 1% level.

labor (particularly in the peak season) from poorer areas along with the flooding of the labor market by the newly evicted tenants may have dampened the rise in wage rates and hence induced less leasing out by landlords. (It can be checked in our model that if there is a rise in the number of total workers available in the peak season—assumed unity in our model—other things remaining the same, tenancy declines.) The introduction of labor-saving devices in some areas also may have contributed to the decline in tenancy, which is consistent with the proposition (*c*) derived from our model. It is also likely that the new agricultural technology makes heavier demands on entrepreneurial decision-making factors as well as on capacity to invest capital, both of which the small sharecropper of yesteryear may have been ill-equipped to provide.

Production Uncertainty

In this section we briefly introduce production uncertainty (say, due to vagaries of weather) and consider the impact of a parametric variation in the riskiness of output on the extent of tenancy. We shall consider only the simpler multiplicative form of uncertainty so that $G(u)Q(BA, L)$ is the production function on the landlord's farm, with u as the random variable representing some index of weather; similarly, $G(u)Q_t(BA_t, L_t)$ is the production function on the tenant farm. We shall assume that the production uncertainty is only for season one; by the time the harvesting season comes the uncertainty is over (this ignores, for example, the possibility of unseasonal rain or hail damaging the ripe crop). If the landlord maximizes his expected utility function with respect to A_t and L, he gets, as necessary conditions for an interior maximum, equation (3) as before; and, instead of equation (4), he gets

$$(26)\quad EU'(Y)\{(1 - \beta w_2)[q(a) - q'(a)a]G(u) - w_1(1 + i)\} = 0,$$

where E is an expectation operator and U is the utility function. Similarly, on the tenant side, instead of equation (7), we now have

$$(27)\quad EU'(Y_t)\{(1 - r - \beta w_2)[q_t(a_t) - q'_t(a_t)a_t]G(u) - \mu w_1(1 + i)\} = 0.$$

The equilibrium condition determining w_2 is given as before by (9), with the difference that $G(u)$ is appended to the production functions; and we shall take this equilibrium to be unique and stable.

We shall define an increase in the riskiness of output in the Rothschild-Stiglitz (1971) sense of a "mean-preserving spread." It is then relatively easy to show with the use of equations (3), (9), (26), and (27), that an increase in production uncertainty induces the landlord to lease out more at a given wage rate w_2, under the sufficient conditions that the degree of absolute risk-aversion $\left[= -\dfrac{U''(Y)}{U'(Y)}\right]$ does not increase as income increases; under a similar condition on the tenant's utility function, an increase in production uncertainty induces him to go more for wage labor at the same wage rate w_2. But in this model, even though we have not introduced any independent source of wage uncertainty, an increase in output uncertainty itself, by affecting demand for and supply of wage labor, changes the equilibrium wage rate. Thus when the equilibrium wage rate itself changes, it turns out to be quite cumbersome to find out which of the conflicting forces prevail. It is, of course, very easy to show that in the special case when the landlord is risk-neutral and the tenant is risk-averse, an increase in production uncertainty reduces the equilibrium percentage of area under tenancy. This result is confirmed by the interstate cross-section data on tenancy in India. For example, there is a significant negative correlation between the percentage of area under tenancy in the different states (as given by the 1960–61 National Sample Survey Land Holdings data) and the coefficient of variation of rainfall (in the states over 1950–62). We have already noted a significant positive association of tenancy with irrigation; to the extent irrigation protects against droughts, this is again a confirmation of the same result.

In this paper we have a two-season model of agricultural production, with labor unemployment in the lean season, land rationing at a conventionally fixed crop share by a monopolistic landlord who is also the financier of consumption credit for the sharecropper families. With comparative-static parametric variations, we have shown that the equilibrium percentage of area under tenancy will be higher in areas where the land quality factor is larger (i.e., soil fertility, rainfall, irrigation, is better), where the crop is more labor-inten-

sive, and where the extent of unemployment facing the landless families is larger. All this is confirmed by interstate cross-section evidence from India in early 1950s. We also have shown in our model that the equilibrium percentage of area under tenancy is likely to be smaller. The larger the degree of imperfection in the market for inputs complementary with high-yielding variety of seeds (or in the market for credit to buy these inputs), the higher the interest rate and the larger the extent of weather uncertainty (if the landlord is risk-neutral and the tenant risk-averse).

[Received March 1978; revision accepted August 1978.]

References

Bardhan, P. K., and T. N. Srinivasan. "Cropsharing Tenancy in Agriculture: A Theoretical and Empirical Analysis." *Amer. Econ. Rev.* 61(1971):48–64.

Bell, C. "Production Conditions, Innovation and Choice of Lease in Agriculture." *Sankhya* Series C. 38(1974):165–90.

Bell, C., and P. Zusman. "A Bargaining Theoretic Approach to Cropsharing Contracts." *Amer. Econ. Rev.* 66(1976):578–88.

Bray, J. O. "Farm Tenancy and Productivity in Agriculture: The Case of the United States." *Food Res. Inst. Stud.* 4(1963):25–38, Stanford University.

Cheung, S. N. S. *The Theory of Share Tenancy.* Chicago: University of Chicago Press, 1969.

Day, R. H. "The Economics of Technological Change and the Demise of the Share-cropper." *Amer. Econ. Rev.* 57(1967):111–23.

Georgescu-Roegen, N. "Economic Theory and Agrarian Economics." *Oxford Econ. Pap.* 12(1960):1–40.

Hayami, Y., and V. W. Ruttan. *Agricultural Development: An International Perspective.* Baltimore, Md.: Johns Hopkins University Press, 1971.

Ishikawa, S. *Economic Development in Asian Perspective.* Tokyo: Hitotsubashi University, 1967.

Johnson, D. G. "Resource Allocation Under Share Contracts." *J. Polit. Econ.* 58(1950):111–23.

Newbery, D. M. G. "The Choice of Rental Contracts in Peasant Agriculture." *Agriculture and Development Theory,* ed. L. Reynolds, pp. 109–37. New Haven, Conn.: Yale University Press, 1975.

Raj, K. N. "Ownership and Distribution of Land." *Ind. Econ. Rev.* 5(1970):1–37.

Rao, C. H. H. "Uncertainty, Entrepreneurship and Share-cropping in India." *J. Polit. Econ.* 79(1971): 578–95.

Reid, J. D. "Sharecropping as an Understandable Market Response in the Post-bellum South." *J. Econ. Hist.* 33(1973):106–30.

Rothschild, M., and J. E. Stiglitz. "Increasing Risk: Its Economic Consequences." *J. Econ. Theory* 3(1971): 66–84.

Sharma, P. S. "Tenancy Situation and Agricultural Productivity in India." *Agr. Situation in India* 23(1968):447–57.

Stiglitz, J. E. "Incentives and Risk Sharing in Sharecropping." *Rev. Econ. Stud.* 41(1974):219–55.

Appendix

Interstate Tenancy and Other Data for India, Early 1950s

States	X_1	X_2	X_3	X_4	X_5	X_6
U.P.	11.38	25.91	28.90	61	63.34	59
Bihar	12.39	17.66	55.72	63	66.32	107
Orissa	12.58	12.89	64.55	54	48.89	60
West Bengal	25.43	18.65	78.49	81	58.47	111
Assam	43.54	20.54	76.02	56	19.37	82
Andhra	19.07	26.47	29.15	n.a.	53.54	n.a.
Madras	27.53	24.61	38.15	60	40.64	145
Mysore and Coorg	16.37	13.01	33.13	65	47.01	98
Travancore and Cochin	23.63	27.80	30.24	61	30.00	108
Bombay	26.81	5.46	9.18	45	23.01	190
Saurashtra and Kutch	6.22	3.22	0.93	84	26.20	126
Madhya Pradesh	18.61	5.36	27.06	37	16.08	90
Madhya Bharat	19.54	4.62	2.34	57	46.32	123
Hyderabad	18.04	5.16	7.18	57	40.77	110
Vindhya Pradesh	21.33	4.52	28.08	68	41.49	n.a.
Rajasthan and Ajmer	20.92	11.23	5.14	57	39.05	119
Punjab (including Delhi and Himachal Pradesh)	40.42	34.82	9.09	59	48.09	226
PEPSU	37.71	41.03	3.92	66	28.37	171
Jammu and Kashmir	22.17	39.03	29.37	n.a.	33.29	175

Note: X_1 is the percentage of cultivated area under tenancy in 1953–54, as estimated from National Sample Survey 8th Round data. X_5, which is the percentage of leased-in area under contracts in which the tenant may be evicted at will, has also the same source of data. X_2 is the percentage of gross sown area irrigated in 1952–53, and the source is the Ministry of Food and Agriculture data. From the same source, we have X_3, the proportion of total cropped area that is under rice, *ragi*, barley, and jute. X_4, the percentage of total annual borrowing by small cultivators that is taken to meet household expenses, relates to 1951–52, is from the All-India Rural Credit Survey Report. X_6, the number of days unemployed in the year 1950–51 for male workers in agricultural labor households, is from the *Report of the Agricultural Labor Enquiry* 1950–51.

The Elasticity of Foreign Demand for U.S. Agricultural Products: The Importance of the Price Transmission Elasticity

Maury E. Bredahl, William H. Meyers, and Keith J. Collins

Johnson and Tweeten (1967, 1977) have provided estimates of the elasticity of export demand for specific agricultural commodities and aggregate agricultural exports. These estimates indicate the aggregate export demand for U.S. agricultural commodities is very elastic with respect to price, and the estimated elasticity is somewhat greater than 6.0 in both cases. The elasticities of export demand for specific commodities are also very large, ranging from −2.8 for soybeans to −10.18 for feed grains (Johnson).

Theoretically, the elasticity of export demand may be quite large. However, the Johnson-Tweeten estimates do not consider government policies which insulate domestic producers and consumers from external price fluctuations. In order to study the effect of these policies on the elasticity of export demand, we (*a*) examine the formulation of the elasticity of export demand and the implication of price insulation policies, (*b*) review the trade policies of major importers and competing exporters, and (*c*) calculate the export demand elasticities for major agricultural commodities which incorporate price insulation policies. These export demand elasticities are much smaller than those of Johnson and Tweeten.

Following Tweeten (1967, p. 361) an appropriate expression for the elasticity of export demand for a commodity is

$$(1) \qquad E_{ef} = \Sigma_i \left[E_{di} E_{pi} \frac{Q_{di}}{Q_{ef}} - E_{si} E_{pi} \frac{Q_{si}}{Q_{ef}} \right],$$

where E_{ef} is the elasticity of export demand, E_{di} and E_{si} are the elasticities of domestic demand and supply in country i; Q_{di} and Q_{si} are the ith country's level of demand and supply, and Q_{ef} is the level of U.S. exports. The elasticity of price transmission (response of the ith country's price to changes in the U.S. price) is E_{pi}. A similar relation is used by Johnson.

A key question that must be resolved in evaluating the elasticity of export demand is the size of the adjustment of foreign prices to U.S. prices, E_{pi}. Johnson states, "E_{pi} is set equal to one and can be ignored" (p. 735). The assumption of perfect price transmission is a convenient simplification but has a profound impact on the calculated elasticities and raises serious questions about their applicability to the real world.

The price transmission elasticity will usually be bounded by zero and one. In the classical free-trade model with zero transportation costs, U.S. and foreign prices would be equal. In this case, the price transmission elasticity would equal one. The price transmission elasticity, also, will be one if the foreign price varies proportionally with the U.S. price ($P_F = eP_{us}$). A price transmission elasticity of one may be termed perfect price transmission.

A free-trade model with nonzero transportation costs will have price transmission elasticities across countries that are less than one. If the foreign price is differentiated by transportation costs or subject to a constant tariff ($P_F = P_{us} + C$), then E_{pi} will be less than one. If the foreign price is less than U.S. price, the case if imports are subsidized ($P_F = P_{us} - C$), E_{pi} will be greater than one.

In cases where governments insulate internal production and consumption prices from world market prices, the E_{pi} will be at or near zero. This insulation requires variable import levies or subsidies on the import side and variable export taxes or subsidies on the export side. The variable levy system of the European Community and the fixed wheat resale price of Japan are examples of this type of policy.

There is strong evidence that for many major importing and exporting regions internal price is largely insulated from U.S. (and/or world market) price. Therefore, for many regions E_{pi} approaches zero and those regions do not contribute significantly to the elasticity of U.S. export demand. The Johnson-Tweeten procedure of calculating a weighted average elasticity based on assumed supply and demand elasticities, while neglecting the size of the foreign price adjustment, will obviously yield an overestimate (in fact, an upper bound) of elasticity of export demand for U.S. agricultural commodities. Tweeten observed (1967, p. 365) that "a sizable upward bias could be present," but does not identify the source of the bias. In order to

---

Maury E. Bredahl, formerly an agricultural economist with ESCS, is assistant professor of agricultural economics, University of Missouri-Columbia. William H. Meyers and Keith J. Collins are agricultural economists, Commodity Economics Division, Economics, Statistics, and Cooperatives Service, USDA.

Rex Daly, James P. Houck, Paul R. Johnson, Jim Matthews, and Paul Gallagher provided helpful comments in the preparation of this paper.

illustrate the effect of domestic price isolation, we will develop a simplification of equation (1) and, using assumed domestic supply and demand elasticities, calculate the implied elasticity of export demand for several commodities.

Method of Analysis

An alternative expression for the elasticity of export demand is derived by dividing the world into major importing and exporting regions. Let Q_{mi} represent the excess demand (imports) of an importing country and Q_{xj} represent the excess supply (exports) of any exporting country except the United States. The demand for U.S. exports is

$$(2) \qquad Q_{ef} = \Sigma_i Q_{mi} - \Sigma Q_{xj},$$

and the elasticity of export demand is

$$(3) \qquad E_{ef} = \Sigma_i E_{pi} E_{edi} \frac{Q_{mi}}{Q_{ef}} - \Sigma_j E_{pj} E_{esj} \frac{Q_{xj}}{Q_{ef}},$$

where all terms are defined except E_{edi} and E_{esj}, which are the elasticities of excess demand and supply of the ith and jth countries, respectively.

Further, the elasticity of excess demand of importers may be derived from the underlying supply and demand elasticities using the identity $Q_{mi} = Q_{di} - Q_{si}$.

$$(4) \qquad E_{edi} = (E_{di} - E_{si}) \frac{Q_{di}}{Q_{mi}} + E_{si}.$$

Similarly, the elasticity of excess supply of exporters is derived from $Q_{xj} = Q_{sj} - Q_{dj}$.

$$(5) \qquad E_{esj} = (E_{sj} - E_{dj}) \frac{Q_{dj}}{Q_{xj}} + E_{sj}.$$

Therefore, to calculate the regional contribution to the elasticity of excess demand for U.S. agricultural commodities, the supply and demand elasticities, the levels of domestic consumption, net imports (exports) and U.S. exports, and the elasticity of price transmission must be known.

The supply and demand elasticities assumed by Johnson seem reasonable and are used in our calculation.[1] Our principal concern is the elasticities of price transmission.

Domestic and Trade Policies

In order to evaluate the response of foreign price to U.S. price, the trade policies of several major importing and exporting regions are reviewed for cereals, soybeans, and cotton (see tables 1 and 2).[2]

For feed grains and wheat, the trade policies of most major importing countries, by and large, insulate the internal consumption price from the U.S. price. Therefore, the elasticity of price transmission with respect to the U.S. price approaches zero in many cases. Some of the assumed zero-foreign price elasticities are subject to debate. The evidence is contradictory for Eastern Europe and the USSR. However, we proceed on the basis that this approach determines a reasonable lower bound for the elasticity of export demand.

Soybeans and soymeal are freely traded commodities on the import side for most regions. Perfect price transmission elasticity ($E_{pi} = 1$) is assumed for these regions. The centrally planned economies are, again, assumed to insulate internal prices, thus, the price-transmission elasticities approach zero.

Cotton is freely traded on the import side. Governments often try to achieve goals with respect to total fiber trade by intervening in the textile rather than the raw fiber markets. Although high duties exist in a number of important cotton-importing countries, these are refunded if the cotton is used in manufacturing textiles for export. Thus, a perfect price transmission is assumed for most cotton-importing countries.

With the exception of wheat, the United States historically has served the role of a residual supplier for the agricultural commodities considered here. Principal competing feed grain and soybean exporting countries export a desired quantity by varying exchange rates, export taxes, and incentives (see table 2). Of critical importance is the insulation of internal consumption and production price from world market price in almost all cases.

An exporting country may vary the intersectoral (from consumption to export) and intertemporal allocation (variation in stocks) of a given level of production in the short run to accommodate world price changes. Data verify that for corn and grain sorghum, stocks have been small relative to production, and consumption has been stable in exporting countries with few exceptions (see Bredahl, Womack, Matthews). Evidence on the intersectoral allocation in soybeans and cotton is mixed; to the extent that the Brazilian wholesale price of soymeal responds to external prices, export supply may be somewhat responsive to price.

In the long run, a country may expand area devoted to a crop or expand cultivated area in response to price changes. This did not happen in competing feed grain-exporting countries during the high prices of 1973–75. Soybean area has expanded rapidly in Brazil. This expansion was prompted by high soybean prices, the destruction of large areas of coffee trees by frost, and the diffusion of technology. However, one thing is certain—the increased soybean area is primarily new agricultural area and is not likely to be withdrawn from production if soybean price declines.

The international trade in wheat is a story requir-

[1] Johnson assumes domestic demand elasticities are −0.2 for wheat and cotton, −0.4 for feed grains and soybeans. All supply elasticities are assumed to be 0.2.

[2] For a more detailed review of importers' and exporters' trade policies for corn and sorghum, see Bredahl, Womack, Matthews. For a review of wheat trade policies, see Gallagher and Bredahl. For a review of soybean trade policies, see Bredahl, Meyers, Hacklander. For a review of cotton trade policy, see International Cotton Advisory Committee.

Table 1. Trade Policies of Major Importing Regions for Important Agricultural Commodities and the Implied Elasticity (E_{pi}) of the Foreign Price with Respect to U.S. Price

Importing Region	Domestic and Trade Policy for Feed Grains	Implied E_{pi}	Domestic and Trade Policy for Wheat	Implied E_{pi}	Domestic and Trade Policy Soybeans	Implied E_{pi}	Domestic and Trade Policy Cotton	Implied E_{pi}
EEC-9	Wholesale prices determined by minimum import prices	0.0	Wholesale price determined by minimum import price	0.0	Free trade	1.0	Free trade. Formal trade agreement (STABEX) with 46 countries influences price	1.0
Other Western Europe	State trading with resale price determined by the state trading agency (Primarily Spain and Portugal)	0.0	State trading with resale price determined by the state trading agency	0.0	State trading in some countries with fixed consumption price	0.0	Free trade	1.0
Eastern Europe	State trading with imports determined by production short falls and livestock production goals	0.0	State trading with imports determined by production short falls and consumption goals	0.0	State trading with imports determined by cereal availability and internal needs	0.0	State trading	0.0
Japan	Free trade	1.0	State trading with a fixed resale price	0.0	Free trade	1.0	Free trade	1.0
USSR	State trading with range of imports determined by formal agreement	0.0	State trading with range of imports determined by formal agreement	0.0	State trading but quantities are very small	0.0	State trading	0.0
ROW	Varies from free trade to highly restricted trade	[a]	Varies from free trade to highly restricted trade	[a]	Mostly free trade	1.0	Varies but mostly free trade	1.0

[a] See text for a discussion of these price transmission elasticities.

ing volumes rather than pages. McCalla hypothesized that until the mid-sixties, implicit collusion between the United States and Canada divided the market and established a world market price. With historically large stocks, the price elasticity of excess supply is obscured by government export policies. Whether price or government policy is affecting exports is unclear. In the short run the excess supply of major competing wheat producers probably is not price responsive because internal consumption price is insulated from world market and U.S. prices. Australia maintains a fixed consumption price. Canada did not significantly increase wheat area in response to high world market prices of the mid-seventies. A behavioral model of the Australian and Canadian wheat boards is a necessary prerequisite to determining the elasticity of wheat excess supply.

The internal production of cotton is influenced in many countries by government-controlled producer prices which are insulated from world market prices. In others, state-run marketing boards purchase all production and control all export. Export subsidies, exchange rate manipulation, and export taxes are important features of the export policies of many exporting countries. The most important charac-

Table 2. Trade Policies of Major Exporting Regions for Important Agricultural Commodities and the Implied Elasticity (E_{pt}) of the Foreign Price with Respect to U.S. Price

Exporting Country	Domestic and Trade Policy for Feed Grains	Implied E_{pt}	Domestic and Trade Policy for Soybeans	Implied E_{pt}
Argentina	Domestic consumption and production prices are fixed. Exports are influenced by variation in exchange rates and export taxes.	0.0	—	—
South Africa	Domestic consumption and production prices are fixed by the South African Maize Board. Variation in exports are primarily associated with variation in production.	0.0	—	—
Thailand	Export quotas with prices determined by U.S. prices allocate almost all of the exportable surplus.	0.0	—	—
Brazil	—	—	Exports determined by available exportable surplus. Exports are encouraged by variation in exchange rates, export taxes and credits.	0.0

Exporting Country	Domestic and Trade Policy for Wheat	Implied E_{pt}	Exporting Country/Region	Domestic and Trade Policy for Cotton	Implied E_{pt}
Canada	All export sales are made by the Canadian Wheat Board. Producer price is determined by the export price with guaranteed minimum prices. Internal consumption price has been fixed during periods of high prices.	[a]	USSR	Production has responded to internal price incentives. These incentives have not followed world market prices.	0.0
Australia	All export sales are made by the Australian Wheat Marketing Board. Internal consumption price is fixed. Producer price is determined by the export price.	[a]	Africa	In most countries, the government is the sole purchaser of cotton. Internal prices are fixed and invariant over long periods. Especially important for Egypt and Sudan.	0.0
			Asia	Syria prices are fixed by the government as a monopoly buyer. Internal prices in Turkey are isolated by export subsidies. Prices in Pakistan are controlled (until recently through the nationalized gin industry). Indian prices have often failed to follow world market prices.	0.0
			Other	Small cotton exporters with internal price variation reflecting world price variation include Iran, Mexico, and some Latin American countries.	1.0

[a] See text for a discussion of these price transmission elasticities.

teristic of foreign cotton production is the insulation of internal producer prices from world market prices. The exceptions, Iran, Mexico, and Latin America, are relatively small cotton exporters.

Export Price Elasticity Estimates

Three measures of the elasticity of export demand are calculated. On the import side, the first two cases use the price transmission elasticities established in table 1. The first assumes the price transmission elasticity of the rest of world (ROW) is zero. This measure is taken as a restricted trade minimum for the elasticity of export demand. For the second case, the price transmission elasticity for the rest of the world is assigned a value of one, implying that internal prices are not insulated by government policies. This estimate, termed restricted trade maximum, may be the closest approximation of the real world. The third case assumes all price transmission elasticities are equal to one. This case includes, but is not limited to, free trade in all importing markets. The free-trade estimate will be considered an upper bound on the elasticity of export demand. On the export side, the United States is explicitly treated as a residual supplier in all three cases. The insulation of production and consumption prices in major exporting countries, for most commodities, justifies this approach.

The estimates are based on the share of total imports held by the United States (Q_{mi}/Q_{ei}), the elasticity of excess demand (E_{edi}), and the assumptions regarding the elasticities of price transmission (E_{pi}). These data are presented in table 3 and the estimates are summarized in table 4.

Comparisons of the three cases, restricted trade-minimum, restricted trade-maximum, and free trade, indicate the importance of the price transmission elasticity in calculating the elasticity of export demand. The difference between cases 2 and 3 indicates the degree to which the elasticity of export demand would increase if agricultural trade moved toward free trade on the import side.

Table 4. The Computed United States Export Demand Elasticities under Alternative Price Transmission Elasticity Assumptions

Commodity	Restricted Trade: Case 1 (Minimum)	Restricted Trade: Case 2 (Maximum)	Case 3 (Free Trade)
Corn	−0.09	−1.31	−3.13
Sorghum	−0.29	−2.36	−2.55
Wheat	0.00	−1.67	−5.50
Soybeans	−0.37	−0.47	−1.12
Cotton	−0.39	−0.65	−1.92

The value obtained for any calculated elasticity depends on a number of assumptions concerning fundamental factors affecting the market for the commodity in question. Many of these assumptions are implicit in the accepted underlying commodity supply and demand elasticities used in the above calculations. Even though these are assumed to be long-run elasticities, the length of run of a computed export demand elasticity derived from them depends on the temporal stability of the elasticities of price transmission. Although it may not be observed empirically, price transmission elasticities may be dynamic and increase as the time period of adjustment lengthens. If this is a characteristic of any of our implied price-transmission elasticities, it would result in larger export-demand elasticities. In the free-trade case, including a domestic demand and supply response in exporting countries also would increase elasticities of export demand to some extent.

Conclusion

This note has focused primarily on the policies of foreign nations aimed at insulating domestic from

Table 3. Share of Total Imports of Selected Regions Accounted for by U.S. Exports for Major Commodities, the Elasticities of Price Transmission, and Excess Demand

Region	Corn Q_{mi}/Q_{ei} [a]	Corn E_{edi} [a]	Corn Assumed E_{pi}	Sorghum Q_{mi}/Q_{ei} [a]	Sorghum E_{edi} [a]	Sorghum Assumed E_{pi}	Soybeans Q_{mi}/Q_{ei} [b]	Soybeans E_{edi} [b]	Soybeans Assumed E_{pi}	Wheat Q_{mi}/Q_{ei} [a]	Wheat E_{edi} [a]	Wheat Assumed E_{pi}	Cotton Q_{mi}/Q_{ei} [b]	Cotton E_{edi} [b]	Cotton Assumed E_{pi}
EEC 9	.518	−1.08	0.0	.200	−0.57	0.0	.600	−0.40	1.0	.34	−1.98	0.0	.87	−.20	1.0
Other Western Europe	.155	−0.80	0.0	.133	−0.62	0.0	.145	−0.41	0.0	.04	−4.92	0.0	.28	−.26	1.0
Eastern Europe	.074	−9.02	0.0	[c]	—	—	.015	−1.44	0.0	.11	−5.52	0.0	.68	−.21	0.0
Japan	.227	−0.39	1.0	.738	−0.39	1.00	.263	−0.42	1.0	.17	−0.40	0.0	.75	−.19	1.0
USSR	.173	−2.72	0.0	[c]	—	—	.026	−1.22	0.0	.24	−6.78	0.0	—	—	—
PRC	[c]	—	—	.00	[d]	—	.067	−8.02	0.0	.15	−4.43	0.0	.27	−4.18	—
ROW	.347	−3.31	?	.674	−3.07	?	.062	−1.57	?	1.11	−1.50	?	.99	−.26	?

Data Source: Cereals and cotton from computer printout provided by the Foreign Agricultural Service; soybeans from *FAO Trade Yearbook 1975*.
[a] Average for July-June years 1972/73–1975/76.
[b] Average for August-July years 1972/73–1975/76.
[c] Included in rest of world (ROW).
[d] Imports are zero; hence, a demand elasticity was not computed.

international price movements. Recently, such policies have been discussed in other contexts (Johnson, Grennes, Thursby; Grennes, Johnson, Thursby). Here we have stressed the need to consider trade and domestic price insulation policies when measuring the elasticity of U.S. export demand. The elasticity-reducing effects of such policies provide an explanation of the discrepancy between the theoretical elasticity computations of Johnson and Tweeten and many empirical elasticity estimates. Consistently, empirical estimates of the elasticity of export demand for specific agricultural commodities are either inelastic or slightly greater than one (Houck, Ryan, Subotnik; Ryan and Houck; Gallagher and Bredahl; Bredahl, Womack, Matthews; Bredahl, Meyers, Hacklander). These estimates may simply reflect the trade restricting behavior of the real world.

In summary, to quote Johnson (1977, p. 735), "There is danger, then, this estimate (Tweeten's) might, through repetition, become a datum for analysis of certain agricultural policy problems." We agree. Our primary concern with theoretically derived estimates of export-demand elasticities is the implicit assumption of perfect price transmission. Our rough estimates, much smaller in absolute value, are in line with many empirical studies and what is known about a world with insulated agricultural markets.

[*Received June 1978; revision accepted October 1978.*]

References

Bredahl, Maury E., Abner Womack, and James Matthews. *The Aggregate Export Demand: Corn and Grain Sorghum.* USDA CED Work. Pap., Feb. 1978.

Bredahl, Maury E., William Meyers, and Duane Hacklander. *The Aggregate Export Demand: Soybeans and Soybean Meal.* USDA CED Work. Pap., Feb. 1978.

Gallagher, Paul, and Maury E. Bredahl. *On the Export Side of Wheat.* USDA CED Work. Pap., 1977.

Grennes, Thomas, Paul R. Johnson, and Marie Thursby. "Insulating Trade Policies, Inventories, and Wheat Price Stability." *Amer. J. Agr. Econ.* 60(1978):132–34.

Houck, James P., Mary Ryan, and Abraham Subotnik. *Soybeans and Their Products.* Minneapolis: University of Minnesota Press, 1972.

International Cotton Advisory Committee. *Government Regulations on Cotton.* Washington, D.C., 1977.

Johnson, Paul R. "The Elasticity of Foreign Demand for U.S. Agricultural Products." *Amer. J. Agr. Econ.* 59(1977):735–36.

Johnson, Paul R., Thomas Grennes, and Marie Thursby. "Devaluation, Foreign Trade Controls, and Domestic Wheat Prices." *Amer. J. Agr. Econ.* 59(1977):619–27.

McCalla, Alex F. "A Duopoly Model of World Wheat Pricing." *J. Farm Econ.* 48(1966):711–27.

Ryan, Mary, and James P. Houck. "A Study of U.S. Exports of Soybeans and Soybean Meal." University of Minnesota Agr. Exp. Sta. Tech. Bull. No. 309, 1976.

Tweeten, Luther. "The Demand for United States Farm Output." *Food Res. Inst. Stud.* 7, 1967.

———. "The Elasticity of Foreign Demand for U.S. Agricultural Products: Comment." *Amer. J. Agr. Econ.* 59(1977):737–38.

Effects of Farm Size on Economic Efficiency: The Case of Pakistan

Mahmood H. Khan and Dennis R. Maki

Many agricultural policy decisions in underdeveloped countries are affected by the belief that the price of increased equity is reduced growth. An important argument used frequently against land reforms, for example, is that large farms are more efficient than small farms. If true, land reforms cannot achieve the dual goals of equity and efficiency. The relative efficiency of large farms, however, may be an illusion if national policies have consistently favored these farms in such a way that their apparent relative efficiency is due to market imperfections in which specific public policies have played a crucial role (Berry and Cline, Griffin). It is evident that better information on the true relative efficiency of large farms would provide a better indication of how agrarian structures affect resource use and thereby of the likelihood of being able to achieve both growth and equity. This paper provides such information for Pakistan.

The concept of efficiency has been interpreted in various ways. An operational concept of economic efficiency has been developed by Lau and Yotopoulos (1971, 1972) and Yotopoulos and Lau, to measure and compare performance of farm firms. Differences in economic efficiency among groups of farms (say large and small) may result from variations in technical efficiency (larger output with equal amounts of inputs) and price efficiency (higher profits). Profit maximization is implied if the value of marginal product of each variable input is equal to its price. Thus we can test relative economic efficiency of large versus small farms by comparing their actual profit functions.

Although the question of relative economic efficiency of large farms is central to a discussion of land reform in underdeveloped countries, there is little empirical research due to lack of adequate disaggregated data. Some evidence for India has been presented by Yotopoulos and Lau (1973), indicating that small farms are more efficient than large farms. However, in studies by Sidhu for wheat in the Indian Punjab and by Khan and Maki for wheat and rice in Pakistan, there was no difference in efficiency by farm size. In this paper, the Lau-Yotopoulos model is used to derive values of technical and price efficiency parameters in order to identify and isolate possible differences between large and small farms. These estimates are based on farm-level data collected from a sample of 728 farms in the Punjab and Sind provinces of Pakistan. Because there are wide differences between these provinces in their agrarian structures, any conclusions drawn from the overall sample would be of dubious value. We, therefore, present estimation results for the provincial samples separately.

Mahmood H. Khan and Dennis R. Maki are associate professors in the Department of Economics and Commerce, Simon Fraser University, Burnaby, Canada.

The Model and Data

Lau and Yotopoulos (1971) have shown that if the assumed production function is of Cobb-Douglas form, then the estimating equation for the profit function is

$$(1) \quad lnP = b_0 + b_1D_L + b_2lnW + b_3lnN + b_4lnK + e_1.$$

The interpretation of results is enhanced if the profit function is jointly estimated with a labor demand function (Lau-Yotopoulos 1972 and Yotopoulos-Lau 1973)

$$(2) \qquad -\frac{WL}{P} = b_5D_L + b_6D_S + e_2.$$

The variables in equations (1) and (2) are defined as P is profit in rupees, (price of output $\times$ physical quantity of output) minus (wage rate per man-day $\times$ number of man-days used), summed over all crop activities on the farm; D_L, the dummy variable, taking the value of unity for large farms; W, the wage rate in rupees per man-day, and is a weighted average of the rates reported for family and hired labor;[1] N, land input, which is net sown area in acres; K, capital input in rupees, and is the sum of costs of seed, fertilizer, tubewell water, and animal and mechanical power; L, man-days of family and hired labor used; D_S, the dummy variable, taking the value of unity for small farms; and e_1 and e_2 are the error terms; and the b_i's are the coefficients to be estimated.

[1] The wage rate for family labor obviously must be an imputed rate, and the imputation used here is that chosen by the respondent. It is in most cases equal to the hired labor rate, but often it is lower. Since the share of family labor is higher on small farms than large ones, an overestimation of the wage rate for family labor would bias b_1 and the absolute value of b_6 upward, or conversely for an underestimation.

The data were collected in 1974 from a sample of randomly selected farmers in eight irrigated districts of the Punjab and Sind (Khan 1975). There are 498 observations for the Punjab and 230 for Sind. "Large" farms are defined as those with 12.5 acres and over. Thus three-quarters of all farms in the sample are large. We also used an alternative definition of large farms, i.e., 25 acres and over, but the coefficient estimates were no different to at least one decimal point, and patterns of significance also did not differ. Therefore, we maintain the conventional definition for large and small farms used in other studies on Pakistan agriculture.

Hypotheses Tested

Since there are no endogenous variables on the right-hand sides of equations (1) and (2), ordinary least squares will yield consistent estimators despite the fact that we are dealing with contemporary related disturbances. However, following previous studies, we apply Zellner's seemingly unrelated regressions method.[2]

The estimation results are given in table 1 for the Punjab and Sind samples. The ordinary least squares (OLS) results are reported for comparison, but are not discussed. All coefficients have expected signs, and with some exceptions (b_1 and b_2) are strongly statistically significant. For each sample, seven null hypotheses are tested. The hypotheses and F statistic values resulting from the tests are presented in table 2. Hypotheses 1 through 5 are tested from the unrestricted estimation; hypothesis 6 with one restriction; and hypothesis 7 with two restrictions. Since much of the interpretation of results depends on the outcomes of the seven tests, it is necessary to specify what is being tested at each step. Each null hypothesis is tested at the 0.05 significance level.

Hypothesis 1 states that the economic efficiency (technical efficiency plus price efficiency) of large and small farms is equal. This hypothesis is rejected; and in both regions, large farms are more efficient (economically).

Hypothesis 2 states that the price efficiency of large and small farms is equal, i.e., they equate the value of marginal product of labor to the wage rate to the same degree. While the hypothesis tested is $b_5 = b_6$, it is more easily conceptualized as $(b_5 - b_2) = (b_6 - b_2)$. This hypothesis is strongly rejected in both samples indicating that large farms are relatively more price efficient in both regions. Also, note that the wage rate exceeds the value of labor's marginal product on all farms in the Punjab and Sind (b_5 and b_6 are both greater than b_2), though the difference is significant only for small farms in Sind.

Hypothesis 3 states that there is equal relative technical and price efficiency jointly between large and small farms. This hypothesis is rejected in both samples, which is not unexpected given the results of hypotheses 1 and 2.

Hypothesis 4 states that large farms have absolute price efficiency, i.e., they maximize profits by equating the value of labor's marginal product to the wage rate. This hypothesis cannot be rejected for either region.

Hypothesis 5 states that small farms have absolute price efficiency. It cannot be rejected for the Punjab, but it is rejected for Sind.

Hypothesis 6 states that there is absolute price efficiency under the maintained hypothesis of equal relative price efficiency. Because hypothesis 2 has been rejected, it makes little sense to test absolute price efficiency under this maintained hypothesis. We include the result for comparison with other studies. The null hypothesis cannot be rejected for the Punjab, but is rejected for Sind.

Hypothesis 7 states that there are constant returns to scale under the maintained hypotheses of absolute price efficiency for large and small farms (and hence of equal relative price efficiency). This hypothesis is rejected in both samples, indicating increasing returns to scale in both provinces. It should be pointed out that this hypothesis would be rejected no matter which estimation in table 1 were used for testing.

Elasticity Estimates

Indirect estimates of production function coefficients can be obtained from the joint estimates of profit and labor demand functions (Lau and Yotopoulos 1972). These estimates are consistent, a property absent in the estimates derived directly from production functions estimated by ordinary least squares. The indirect elasticity estimates are reported in table 3. The following formulas, derived from Lau and Yotopoulos (1972), show the correspondences between the estimated coefficients in tables 1 and 3.

$$a_1 = b_2/(b_2 - 1), \tag{3}$$

$$a_2 = b_3/(1 - b_2), \text{ and} \tag{4}$$

$$a_3 = b_4/(1 - b_2). \tag{5}$$

[2] The results of Lau and Yotopoulos (1971) have been criticized by Maddala (pp. 69, 273–74) because they ignored heteroscedasticity and had potential bias due to grouped data. We have micro data, eliminating the latter difficulty, but heteroscedasticity is still a potential problem. Applying the Goldfeld-Quandt test (Murphy, p. 304) to test for heteroscedasticity between large and small farms using OLS estimation yielded F values of 1.23 with (362, 128) degrees of freedom for the Punjab, and 2.19 with (54, 168) degrees of freedom for Sind. Thus, at the .05 level, there is no indication of heteroscedasticity in the Punjab, but there is in Sind. Consequently, all observations for large farms in Sind were divided by 0.45266 and for small farms by 0.67043 (the standard errors of estimate from the separate OLS regressions) prior to obtaining the estimates reported in table 1. Analysis of the residuals from the pooled OLS regression for Sind reveals that this procedure alleviated the heteroscedasticity problem, as the ratio of the variances of residuals for small versus large farms is only 1.21.

Table 1. Joint Estimation of Profit Function and Labor Demand Function

Regressions	Estimated Coefficients for the Profit Function					Estimated Coefficients for the Demand Function	
	b_0	b_1	b_2	b_3	b_4	b_5	b_6
The Punjab (498 farms)							
OLS	4.741	−.060	−.319	.942	.297	−.112	−.257
	(16.59)	(−1.16)	(−1.95)	(15.58)	(5.72)	(−21.55)	(−29.81)
Unrestricted	4.574	.182	−.029	.749	.319	−.112	−.257
	(19.45)	(3.88)	(−0.22)	(15.09)	(7.49)	(−21.55)	(−29.81)
One restriction	4.768	−.086	−.115	.806	.312	−.150	−.150
	(19.00)	(−1.89)	(−0.80)	(15.19)	(6.86)	(−28.37)	(−28.37)
Two restrictions	4.808	−.086	−.150	.798	.318	−.150	−.150
	(24.09)	(−1.88)	(−28.37)	(16.80)	(7.71)	(−28.37)	(−28.37)
Three restrictions	5.058	.005	−.150	.666	.334	−.150	−.150
	(27.04)	(0.18)	(−28.36)	(16.59)	(8.32)	(−28.36)	(−28.36)
Sind (230 farms)							
OLS	2.375	.252	−.283	.567	.693	−.275	−1.385
	(4.81)	(0.95)	(−2.05)	(8.24)	(10.33)	(−2.40)	(−7.01)
Unrestricted	2.464	.510	−.134	.502	.669	−.275	−1.385
	(5.53)	(2.00)	(−1.08)	(8.12)	(11.09)	(−2.40)	(−7.01)
One restriction	2.607	.075	−.148	.508	.671	−.555	−.555
	(5.80)	(0.31)	(−1.18)	(8.12)	(11.01)	(−5.33)	(−5.33)
Two restrictions	3.156	−.002	−.394	.571	.633	−.394	−.394
	(8.01)	(−0.01)	(−4.88)	(9.80)	(10.59)	(−4.88)	(−4.88)
Three restrictions	4.148	.500	−.343	.478	.522	−.343	−.343
	(12.55)	(2.44)	(−4.24)	(8.61)	(9.41)	(−4.24)	(−4.24)

Note. t values are given in parentheses; 1 Restriction: $b_5 = b_6$; 2 Restrictions: $b_2 = b_5 = b_6$; 3 Restrictions: $b_2 = b_5 = b_6$, $b_3 + b_4 = 1$.

The elasticity estimates in table 3 for farms in the Punjab and Sind have the expected signs. The most striking point is the much larger input elasticity for land in the Punjab than in Sind, with the converse for capital. For policy implications, it is instructive to examine some coefficients estimated in table 1 as elasticities. The labor demand elasticities with respect to wage rate, land, capital, and price of output, respectively, are for the Punjab, −1.15, 0.67, 0.33, and 1.15; and for Sind, −1.34, 0.48, 0.52, and 1.34. The reduced form output elasticities with respect to wage rate, land, capital, and price of output, respectively, are for the Punjab: −0.15, 0.67, 0.33, and 0.15; and for Sind: −0.34, 0.48, 0.52, and 0.34. The output elasticities with respect to land and capital indicate changes in output from exogenous changes in these inputs, holding the wage rate and not the quantities of labor constant. A given

Table 2. Tests on Hypotheses Regarding Relative Efficiency of Large and Small Farms

Hypotheses: Maintained	Hypotheses: Tested	Computed F Ratios (Degrees of Freedom): Punjab	Computed F Ratios (Degrees of Freedom): Sind
	(1) $b_1 = 0$	15.02 (1,491)	3.99 (1,223)
	(2) $b_5 = b_6$	209.21 (1,491)	23.63 (1,223)
	(3) $b_1 = 0$ and $b_5 = b_6$	115.73 (2,989)	11.95 (2,453)
	(4) $b_5 = b_2$	1.79 (1,491)	0.69 (1,223)
	(5) $b_6 = b_2$	0.07 (1,491)	28.77 (1,223)
$b_5 = b_6$	(6) $b_5 = b_2$ (or $b_6 = b_2$)	0.06 (1,492)	6.22 (1,225)
$b_5 = b_6$, $b_5 = b_2$	(7) $b_3 + b_4 = 1$	24.22 (1,493)	17.94 (1,225)

Note: Critical values are $F_{.95}$ (1, ∞) = 3.84, $F_{.95}$ (2, ∞) = 3.00.

Table 3. Indirect Estimates of Production Function Coefficients

Coefficient	None	Restrictions One	Two	Three
The Punjab				
Labor a_1	.028	.103	.131	.131
Land a_2	.728	.723	.694	.579
Capital a_3	.310	.280	.276	.290
$a_1 + a_2 + a_3$	1.066	1.106	1.101	1.000
Sind				
Labor a_1	.118	.129	.283	.255
Land a_2	.443	.442	.410	.356
Capital a_3	.590	.585	.454	.389
$a_1 + a_2 + a_3$	1.151	1.156	1.147	1.000

increase in land (capital) shifts the marginal product curves of all factors, i.e., more inputs are used than before.

Interpretation of Results and Conclusions

In comparing the results for the Punjab and Sind of tests performed on hypotheses of efficiency and returns to scale, we find that large farms are more efficient than small farms by 18% in the Punjab and 51% in Sind. It is also evident that both large and small farms maximize profits in the Punjab, while in Sind large farms maximize profits but small farms pay labor more than its marginal product.

The direct implications of these results would be that land consolidation and other policies designed to encourage large farms should be undertaken if efficiency is the paramount consideration. At the very least, the results indicate that policies with respect to ceilings on land holdings and land redistribution cannot be guided solely by equity considerations, as there will be efficiency effects.

We feel it premature, however, to discuss land distribution policies without more information on the causes of the better performance of large farms. There is considerable evidence, indicated below, that large farms have a comparative advantage in obtaining and utilizing information on the use of new inputs and the ability to obtain needed inputs and credit. Further, this advantage may be due in large part to previous public policy decisions and agrarian structures, not to inherent characteristics of "size."

The first link in this argument is the observation that input use varies between large and small farms and between the Punjab and Sind in a manner consistent with the hypothesis that efficiency is correlated with the levels of use of certain inputs. Table 4 presents the aggregate data on the use of selected inputs by farm size. With the exception of fertilizer, the use of inputs is much greater in the Punjab than in Sind, and the differences between large and small farms for tubewells and tractors is more pronounced in Sind than in the Punjab. It should also be pointed out that for the farm samples in this study the amount of fertilizer used per acre increases with the size of farm in both regions (Khan 1977). Furthermore, large and small farms in the Punjab use more fertilizer per acre than their counterparts in Sind (Esso, Khan 1975).

The second link in the argument pursued here relates to differences in agrarian structures. These differences are presented in table 5, using data from the agricultural censuses of 1960 and 1972. Despite changes during the intercensus period, in 1972, 63% of all farms in Sind were tenant farms. More important, tenant farms were more dominant among small farms: 68% of small and 50% of large farms were tenant farms. In the Punjab, on the other hand, only 29% of all farms were tenant farms. What is even more striking in the Punjab is that small farms have proportionately more owner farms (47%) than do large farms (33%). If access to inputs is easier for large farms than small farms, and for owners than tenants, it can be seen why small farms would use less of modern inputs per acre, especially in Sind where these farms are dominated by tenants and tenancy conditions are traditionally the more insecure.

The final link in the argument deals with the effects of previous public policy decisions. During the sixties and early seventies, increasing numbers of tractors imported into the country, mainly for use on large farms, were subsidized by the Agricultural Development Bank of Pakistan (ADBP) through its loan policy and interest rates (IBRD 1975). Similarly, most of the private tubewell technology and use of fuels have been subsidized, partly by price policy for imported materials and partly by the terms on which the ADBP loans have been given in the main to large farms (Pakistan 1975). Private tubewells are an additional source of irrigation water to the already subsidized canal water supplied by the state (Chaudhry). In 1972–73, the extent of subsidy on fertilizer was estimated at 35%, and the government spent Rs. 207 million on this subsidy. These figures were given in 1974 by the Food and Agriculture Section, Pakistan Planning Commission. Studies on farm extension services and on marketing channels for fertilizer indicate that large farms have greater access to information on fertilizer use and the input itself (Dalrymple, pp. 3–17). Other studies have shown that the percentage of farmers complaining about credit as a constraint on fertilizer use declined with farm size (Azam, Esso). Finally, and perhaps most important, large farms in Pakistan have enjoyed more favorable, if not exclusive, access to institutional credit for capital expenditure at rates of interest that do not reflect the opportunity cost of these funds. For example, in our sample of data all loans from the ADBP were received by farms of over 25 acres, and the rate of interest varied from 7% to 8% per year (Khan 1975, pp. 104–7).

We speculate that these considerations constitute the most important factors explaining the greater observed efficiency of large farms. It was impossi-

Table 4. Use of Selected Inputs by Farm Size in the Punjab and Sind, 1972

Farm Size and Province	Number of Tractors per 1000 Acres of Farm Area	Number of Power-Driven Implements per 1000 Acres of Farm Area	Number of Private Tubewells per 1000 Acres of Farm Area	Percentage of Farms Using Fertilizer	Percentage of Cropped Area Fertilized
Large farms					
Punjab	1.07	0.44	3.93	59.54	43.64
Sind	0.54	0.31	0.82	65.53	52.86
Small farms					
Punjab	0.24	0.06	3.60	52.18	43.03
Sind	0.06	0.05	0.18	57.03	44.17
All farms					
Punjab	0.83	0.33	3.83	54.75	43.44
Sind	0.35	0.21	0.57	59.53	48.60

Source: Pakistan, Agricultural Census Organization. *Pakistan Census of Agriculture 1972*, vol. *1*. Islamabad, 1976.

ble to test the influence of these factors, particularly the potentially important tenancy factor, given our data set, but such testing constitutes an important direction for future research (Gotsch et al.). Pending the completion of such research, our findings should not be naively used for policy purposes.

[Received April 1977; revision accepted July 1978.]

References

Azam, K. M. "The Future of the Green Revolution in Pakistan." *Int. J. Agrarian Aff.* 5(1973):404–29.

Berry, R. A., and W. R. Cline. "Farm Size, Factor Productivity and Technical Change in Developing Countries." Mimeographed. Washington, D.C., The World Bank, June 1976.

Chaudhry, M. S. "Economic Impacts of Wheat Yield Increases in West Pakistan." Ph.D. thesis, Washington State University, 1971.

Dalrymple, D. *Evaluating Fertilizer Subsidies in Developing Countries*. Washington, D.C.: Agency for International Development Disc. Pap. No. 30, July 1975.

Esso Pakistan Fertilizer Co. *Pakistan Nitrogen Demand Forecast Study, 1974/75 to 1984/85*. Karachi, June 1974.

Gotsch, Carl H., Bashir Ahmed, Walter P. Falcon, Muhammad Naseem, and Shahid Yusuf. "Linear Programming and Agricultural Policy: Micro Studies of the Pakistan Punjab." *Food Res. Inst. Stud.*, no. 1, 1975.

Griffin, K. *The Political Economy of Agrarian Change: An Essay on the Green Revolution*. Cambridge, Mass.: Harvard University Press, 1974.

International Bank for Reconstruction and Development. *The Consequences of Farm Tractors in Pakistan*. Washington, D.C., Feb. 1975.

Khan, M. H. *The Economics of the Green Revolution in Pakistan*. New York: Praeger Publishers, 1975.

———. "Farm Size and Land Productivity Relationships in Pakistan." Burnaby, B.C., Canada: Dep. Econ. and Commerce, Simon Fraser University, May 1977.

Table 5. Distribution of Farms by Ownership in the Punjab and Sind, 1960 and 1972

Farm Size and Province	Number of Farms (in '000')		Percentage Distribution: Owner Farms		Owner-cum-Tenant Farms		Tenant Farms	
	1960	1972	1960	1972	1960	1972	1960	1972
Large farms								
Punjab	715	830	34	33	26	37	40	30
Sind	241	220	22	30	15	20	62	50
Small farms								
Punjab	2,611	1,545	45	47	17	24	38	28
Sind	439	528	19	21	5	10	76	68
All farms								
Punjab	3,326	2,375	43	42	19	29	39	29
Sind	680	748	20	24	9	13	71	63

Source: Government of Pakistan, Agricultural Census Organization. *1960 Pakistan Census of Agriculture*, vol. *2*. Karachi, 1963; *Pakistan Census of Agriculture 1972*, vol. *1*. Islamabad, 1976.

Khan, M. H., and D. R. Maki. "Relative Efficiency by Farm Size and the Green Revolution in Pakistan." Dep. Econ. and Commerce, Disc. Pap. 77-9-1, Simon Fraser University, Jan. 1977.

Lau, L. J., and P. A. Yotopoulos. "A Test for Relative Efficiency and Application to Indian Agriculture." *Amer. Econ. Rev.* 61(1971):94–109.

———. "Profits, Supply, and Factor Demand Functions." *Amer. J. Agr. Econ.* 54(1972):11–18.

Maddala, G. S. *Econometrics*. New York: McGraw-Hill Book Co., 1977.

Murphy, J. L. *Introductory Econometrics*. Homewood, Ill.: Richard D. Irwin, 1973.

Pakistan, Agricultural Census Organization. *1960 Pakistan Census of Agriculture*, vol. *2*. Karachi, 1963.

———. *Pakistan Census of Agriculture 1972*, vol. *1*. Lahore, 1976.

Pakistan, Ministry of Food, Agriculture, Cooperatives, Underdeveloped Areas, and Land Reforms. *Agricultural Statistics of Pakistan 1975*. Islamabad, 1975.

Sidhu, S. S. "Relative Efficiency in Wheat Production in the Indian Punjab." *Amer. Econ. Rev.* 64 (1974):742–51.

Yotopoulos, P. A., and L. J. Lau. "A Test for Relative Economic Efficiency: Some Further Results." *Amer. Econ. Rev.* 63(1973):214–23.

Zellner, A. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *J. Amer. Statist. Assoc.* 57(1962):348–75.

Toward an Optimal Rate of Growth in Agricultural Production Research and Extension

Marlys Knutson and Luther G. Tweeten

Publicly supported investments in nonconventional inputs, principally agricultural production research and extension (R), contributed significantly to gains in productivity and have been a low-cost source of additional output. Several studies (Peterson; Tweeten, 1970, chap. 5) reveal rates of return clustering around 50% on public R investment.

Ironically, this rate of return implies economic inefficiency—the nation has foregone production from greater use of low-cost sources of farm output. In competitive equilibrium, an efficient allocation entails an equal rate of return among alternative investments, given appropriate adjustment for risk. For economic efficiency, more investment is called for in agricultural research and extension to drive the rate of return down to levels consistent with returns on alternative uses for limited funds. Previous studies show only the historic rate of return on R investment. Such estimates are of limited use in judging appropriate future levels of R. The purpose of this study is to determine a more nearly optimal rate of future investment in publicly supported agricultural production research and extension. Specific objectives include: (*a*) Updating previous estimates of rates of return on past investments in R; (*b*) Estimating expected rates of return on alternative future levels of investment in R, showing investments required to reduce the rate of return to a more nearly optimal level; (*c*) Examining the impact on future farm prices, income, and usage of conventional production inputs associated with alternative rates of growth in farm productivity; and (*d*) Inferring tentative conclusions regarding optimal growth in R consistent with equilibrium rates of return in (*b*) and the ability of the farming industry to adjust to productivity gains as determined in (*c*).

Previous Studies

Since the early work of Griliches (1958, 1964), techniques measuring the contribution of R to agricultural productivity have become more sophisticated. Studies distribute returns to research through time, with investment of R in time period t_o bringing increasing marginal contributions to farm output to t_m and decreasing marginal contributions from t_m to t_s. This procedure recognizes time lags in development and adoption of technology as well as depreciation of benefits as, for example, new crop varieties become susceptible to damage from pests or are replaced by improved technologies. Evenson's study used the mean lag between investment and total obsolescence (t_s) of 5.5 years for state-supported research and 8.5 years for federally supported research. Cline used a parabolic distribution of marginal contributions, whereas Evenson assumed a triangular distribution of marginal responses over time. The full contribution of R to output is the sum of the marginal contributions. Evenson's estimated internal rate of return to public R was 57%. Adjusting for private research (by a factor of 1.22) reduced the estimate to 48%.

Model

The value of the aggregate productivity index P at a particular time t is given by the ratio of productivity in the current period (A_t) to productivity in the base period (A_o).

$$P_t = \frac{A_t}{A_o}, \text{ or} \tag{1a}$$

$$\ln P_t = \ln A_t - \ln A_o. \tag{1b}$$

To estimate this productivity change model, productivity is viewed as a function of public sector R in the current period and in preceding periods (R_{t-i}, $i = 0, 1, \ldots, n$), public sector nonproduction-oriented research and extension expenditures in the current period (O_t), an index of educational attainment of farmers and farm laborers in the current period (E_t), and the value in the current period of a weather index (W_t). Variables other than R_{t-i} can be viewed as controls. In log form, the equation (Cline, p. 88) is

$$\ln P_t = \sum_{i=0}^{n} \beta_i \ln R_{t-i} + \beta_{n+1} \ln O_t + \beta_{n+2} \ln E_t + \beta_{n+3} \ln W_t + U_t. \tag{2}$$

Marlys Knutson and Luther Tweeten are, respectively, research assistant and regents professor, Department of Agricultural Economics, Oklahoma State University.

Journal article J-3397 of the Oklahoma Agricultural Experiment Station, Stillwater.

The assistance of Cliff Carmen, National Economic Analysis Division, Economic Research Service, U.S. Department of Agriculture, in providing economic projections from the NIRAP system is gratefully recognized by the authors.

This relationship was estimated by Cline with autoregressive least squares using the polynomial distributed lag technique, where U_t is the disturbance in year t.

Since Cline's study, revisions were made by the U.S. Department of Agriculture (USDA) in the productivity index. Revisions were slight for the years 1929–72 used by Cline to estimate the production function for R and E. Because the slight revisions in the productivity data for the 1929–72 period did not seem to warrant reestimating Cline's production function, we utilized his function for our analysis.

Cline's results are shown in table 1 for (2), estimated with U.S. annual data from 1929–72 with O_t omitted because its coefficient was large relative to its standard error. Only sums of the β_i are shown for selected lags to save space, but the coefficients for each lag display the parabolic pattern.

Although the standard error of the estimate is slightly larger for the 16-year lag than for the 13-year lag, we select the 16-year lag based on discussions with agricultural scientists who judged that at least eight years are required for the average research and extension input to have maximum impact on output and at least sixteen years are required before the input no longer influences output. In general, the statistical results follow a consistent pattern, but the sum of coefficients ($\Sigma\ \beta_i$) of lagged research and extension inputs is smaller for the 13-year lag than for the 12-year or 16-year lag.

The internal rate of return, defined as the highest interest rate that could be paid on R outlays and just break even on the investment, is computed as that discount rate which makes the present value of the marginal product of R less the cost of R equal to zero. Following Cline, we calculate the marginal product of R from estimates of B_i.

It is apparent that the elasticity of the productivity index with respect to research and extension input from (2) is

$$\frac{\partial lnP_t}{\partial lnR_{t-i}} = \frac{\partial P_t}{\partial R_{t-i}} \frac{R_{t-i}}{P_t} = \beta_i. \tag{3}$$

The marginal product MP_t of R_{t-i} is

$$\begin{aligned} (4)\ MP_t = \frac{\partial Y_t}{\partial R_{t-i}} &\simeq \frac{\partial P_t}{\partial R_{t-i}} \frac{\Delta Y_t}{\Delta P_t}\ (i = 0, 1, \ldots, n) \\ &\simeq \frac{\partial P_t}{\partial R_{t-i}} \cdot \frac{R_{t-i}}{P_t} \frac{P_t}{R_{t-i}} \frac{\Delta Y_t}{\Delta P_t} \\ &\simeq \frac{\beta_i P_t}{R_{t-i}} \frac{\Delta Y_t}{\Delta P_t}. \end{aligned}$$

Marginal products and internal rates of return are estimated for periods, usually a decade in length. Marginal products (4) for each year in a period are calculated by multiplying β_i times the ratio of average productivity to average R_{t-i} input during the period. ΔP_t is the ending less beginning value of P, and ΔY_t is the increase in output attributed to productivity gains. The USDA provides data directly suited to estimating ΔY_t for historic series, as considered in the following section. The projected series procedures, to be defined later, for calculating ΔY_t are more complex.

Historic Rates of Return

We employed Cline's methodology to determine estimates for both a 13-year lag and a 16-year lag for

Table 1. Regression Results from Estimating Equation (3) with Autoregressive Least Squares Using the Polynomial Distributed Lag Technique and U.S. Data for 1929–1972

Explanatory Variable	Lag Length (number of years)					
	10	12	13	14	15	16
$ln\ R_{t-i}$[a] $\left(\sum_{i=0}^{n} \beta_i\right)$	.0249	.0438	.0369	.0515	.0519	.0595
$ln\ E_t$	.8209	.7663	.7851	.7501	.7493	.7299
	(3.9249)[b]	(3.2118)	(3.0440)	(2.8138)	(2.6632)	(2.5554)
$ln\ W_t$	.0018	.0021	.0020	.0020	.0020	.0020
	(4.1122)	(4.7306)	(4.7337)	(4.4566)	(4.3708)	(4.3906)
$\bar{R}^2$	.999	.999	.999	.999	.999	.999
SEE[c]	.02185	.02113	.02036	.02060	.02101	.02116
DW[d]	2.34	2.14	2.29	2.30	2.29	2.20
$\hat{\rho}$[e]	.756	.795	.839	.830	.830	.819

Source: Cline, p. 88.

[a] A joint F test for each equation of the null hypothesis that all the regression coefficients for the R's are equal to zero was rejected at the 1% level of significance in each case.

[b] Numbers in parentheses are t-values.

[c] Standard error of the estimate.

[d] Durbin-Watson "d" statistic.

[e] The estimated value of the first-order autoregression coefficient of the disturbances.

R (table 2). Rates of return are higher for the longer lag and both lags show a decreasing trend in the rate of return through time. Our estimated returns for the 13-year lag were somewhat higher than Cline's. For example, our rate for the 1969–72 period was 28.0% compared to Cline's 23.5%. A careful check of procedures and communication with Cline did not uncover the basis for the difference. We deem our computational procedure to be reliable. The differences between our estimates and Cline's do not arise from a change in the production function itself.

The real growth in R investment averaging approximately 3% annually has resulted in diminishing returns, according to results in table 2. One question to be answered is whether continued growth of investment at this rate will reduce rates of return to optimal levels within a reasonable time frame or whether additional funding is warranted.

The equilibrium rate of return or appropriate discount rate for use in public investment decisions has long remained a point of controversy. Given alternative uses for funds and considering that risk is considerably less when viewed from the standpoint of the public than of the private firm, a 10% rate of return may be appropriate for this analysis. However, the reader can judge outcomes in table 4 based on whatever rate of return he/she deems to be appropriate.

The National Research Council of the National Academy of Sciences (p. 41) came to a tentative conclusion concerning the amount by which R should increase:

> The steering Committee does not know what the optimum food and nutrition research budget level should be for the next few years. . . . We believe that an overall food and nutrition research budget increase, compared to FY1974, of at least 50 percent in real terms over the next two or three years is needed to make a strong start on the new priorities, and that a steadily rising real expenditure trend is essential over the next decade and beyond to do justice to the purpose of reducing world hunger and malnutrition.

The Board on Agriculture and Renewable Resources (p. 9) supported the need for a large immediate increase:

> We recommend a substantial increase of support for research directed toward the production, dependability, and quality of the food supply. Financial support for such research should be increased to restore at least the 1966 buying power. . . . State and federal support—now totaling about $450 million per year—for research related to agricultural productivity should be increased immediately by 40 percent.

Table 2. Marginal Internal Rates of Return (%) to Production-Oriented Research and Extension during Specified Time Periods

Period	13-Year-Lag	16-Year-Lag
1939–48	40.9	49.7
1949–58	38.8	47.4
1959–68	31.6	39.4
1969–72	28.0	35.5

With this background, we now estimate the rate of growth in R necessary to bring the rate of return to a more nearly optimal level and also project the impact of greater R outlays on the farming economy.

Projected Economic Outcomes

Marginal products and rates of return on investment in R are projected from 1976 to 2015 under various scenarios defining the rate of increase in R, demand for farm output, and inflation using two modeling approaches.

Scenarios

Three alternative real growth rates in R were considered in the analysis: (*a*) A constant 3% per year increase, 1976–2015, (T_3), the historical average rate from 1939 to 1972; (*b*) A 10% per year increase during the period 1976–80 in keeping with recommended rated cited earlier, followed by a 3% per year increase from 1981 through 2015 ($T_{10/3}$); and (*c*) A 10% per year increase during the period 1976–80, followed by a 7% per year increase from 1981 through 2015 ($T_{10/7}$).

Real R outlays were allowed to increase no more than 10% annually to avoid sharply diminishing returns as increased funding presses against a limited short-run supply of scientists and apparatus. Although the empirical estimates of equation (2) depict diminishing returns from increasing R, rates of increase in excess of 10% per year for R would be too far outside the range of historical observation to provide meaningful results.

Table 3 summarizes these scenarios and attendant projected annual percentage growth in agricul-

Table 3. Annual Compound Rate of Growth (%) in U.S. Agricultural Productivity (Output per Unit of Conventional Inputs) under Various Scenarios by Selected Time Periods, 1976–2015

	Scenario		
Period	T_3	$T_{10/3}$	$T_{10/7}$
1976–1985	1.036	1.102	1.115
1986–1995	.954	1.032	1.173
1996–2005	.866	.866	1.072
2006–2015	.801	.801	.986

Note: Productivity growth was estimated from equation (2) with lag length of 16 years as shown in table 1.

tural productivity for the various combinations of assumed percentage increases in demand and R expenditures. Annual productivity gains shown in the table may be compared with annual percentage rates of growth in output per unit of conventional inputs averaging 2.34% in the 1950s, 1.04% in the 1960s, and 1.09% from 1970–75. Productivity growth rates may seem unusually low in table 3 but this is a direct result of the small proportion (less than 2%) of R in the total dollar value of agricultural inputs.

The scenarios for growth for farm output, including discussion of exports and domestic population and income components, have been presented in some detail by Tweeten (1976) and by Yeh, Tweeten, and Quance. The most likely or baseline estimate of 1.5% conforms with baseline export growth of 3.5%, U.S. population growth of .68%, and per capita real disposable personal income growth of 2.7%. It is designated $D_{1.5}$ and termed the "baseline" case. Results are also shown for demand increasing 1.2% annually ($D_{1.2}$) and 2.1% annually ($D_{2.1}$) to show sensitivity of results to alternative rates of growth in demand. In scenarios where inflation is allowed, the rate of increase in prices paid by farmers was held constant throughout the analysis at 4% annually.

Approaches

Rates of return and marginal products for R investments were calculated for 10-year periods from 1976 through 2015 using two modeling approaches. The first "standard" approach uses rates of growth in demand and R depicted earlier and assumes that increasing productivity or inflation in prices paid by farmers have no macroeconomic impact on the behavior of farmers or on farm output. Given the projected rate of increase r (see table 3) in productivity P and the assumed rate of growth d in demand for farm output, the increase in output associated with R in each period is

$$(5)\quad \Delta Y_t = Y_0 e^{dt}\left(1 - \frac{1}{e^{rt}}\right) = Y_t\left(1 - \frac{1}{e^{rt}}\right).$$

The results for this series, labeled the standard approach, overestimate gains in output from productivity because the model fails to account for higher productivity reducing farm prices (demand effect) which, in turn, retard growth in farm output (supply effect). Accordingly, the National-Interregional Projections (NIRAP) system (see Yeh) was employed to account for supply-demand impacts on ΔY and hence on the marginal product and rates of return. Results from this form of the model, labeled the NIRAP approach, include measures of farm income, prices, and other projected outcomes presented later. The standard approach results are included for two reasons: (*a*) to provide a benchmark against which to compare the macroeconomic effects accounted for in the conceptually more attractive NIRAP model; and (*b*) to provide basic estimates for those who prefer to omit results from the NIRAP model.

The NIRAP model (see Yeh) simulates the impact on the farming economy of increasing productivity and the assumed 4% annual inflation in prices paid by farmers. Because supply shifts to the right from increased productivity at a slower rate than demand in all scenarios, other things equal, this macroeconomic effect would increase marginal products and rates of return over those of the standard approach. However, the macroeconomic effects of inflation restrain use of conventional inputs, decreasing output, *ceteris paribus*. Thus, inflation accounts for the lower marginal product and rates of return computed from the NIRAP model. In all cases in table 4, marginal products and rates of return are estimated with R outlays and farm output in real 1967 dollars. Rates of return were also calculated with inflated values of R and farm output but are not shown because they differed little from those shown in table 4.

Some Generalizations

Based on results in table 4, the increase in R outlays recommended by sources cited above is broadly consistent with reaching an economic equilibrium by 2006–15 if demand grows at 1.5% annually and real growth in R is held to 3% annually after 1980. If demand increases by only 1.2% annually, increasing real research outlays by more than the historic average of 3% per year does not seem warranted in the long run. If demand increases by more than 1.5% per year, even larger increments in R may be warranted, however.

Time and resource limitations precluded examining additional scenarios, but it is possible to speculate briefly on some alternatives. One possibility would be to increase real R outlays 4% annually from 1976 to 2015, giving the same total R by 2015 as the $T_{10/3}$ alternative. The advantage of the 4% rate of increase is the absence of "shocks" to the R system from abrupt changes in the rate. The disadvantage is efficiency losses—the intent of $T_{10/3}$ is to achieve efficiency gains by bringing the rate of return on R more nearly to the equilibrium level at an earlier date.

It might seem attractive to pursue $T_{10/7}$ to 1995, then substantially cut back R. This approach could not avoid negative rates of return because returns after 1995 are predetermined by investments prior to that date.

Ultimately, R outlays can increase no faster than the rate of growth in demand for farm output. If the rate of growth in R exceeds the rate of growth in demand for an extended period, nonconventional resources would comprise more than the value of farm output. This suggests that in the case of $D_{1.5}$ $T_{10/3}$, the rate of increase in real R could be reduced to near the rate of growth in demand sometime during the first or second decade after 2000. Of

Table 4. Estimated Marginal Products and Rates of Return on *R* and Selected Economic Outcomes for the Farming Industry under Various Scenarios by Selected Time Periods, 1976–2015

		STANDARD APPROACH		NIRAP APPROACH							
						Parity Ratio		Net Farm Income		Conventional Farm Inputs	
Scenario	Period	Sum of Marg. Prods. ($)	Rate of Return (%)	Sum of Marg. Prods. ($)	Rate of Return (%)	Beginning Year	Ending Year (1910–14 = 100)	Beginning Year	Ending Year (Billion Current $)	Beginning Year	Ending Year (Billion 1967 $)
$D_{1.5}\ T_2$	1976–1985	5.84	35.8	5.49	33.6	75.13	70.23	21.9	23.8	47.6	44.9
	1986–1995	4.92	30.2	4.18	25.6	69.55	64.38	23.5	20.5	44.5	41.2
	1996–2005	4.15	25.4	3.22	19.3	63.87	60.98	20.0	18.2	40.9	38.6
	2006–2015	3.50	21.1	2.53	14.2	60.69	58.06	17.8	11.3	38.4	37.1
$D_{1.5}\ T_3$	1976–1985	6.03	36.8	5.62	39.4	76.00	72.67	23.0	28.9	47.8	46.1
	1986–1995	5.23	32.1	4.39	26.9	72.14	68.23	29.1	32.0	45.8	43.2
	1996–2005	4.55	27.9	3.46	20.9	67.85	66.18	32.3	41.2	42.0	41.5
	2006–2015	3.95	24.1	2.78	16.2	66.02	64.53	42.5	54.5	41.4	40.9
$D_{2.1}\ T_3$	1976–1985	6.41	39.1	5.91	36.1	77.77	78.02	25.4	40.9	48.2	49.4
	1986–1995	5.91	36.1	4.87	29.9	77.90	77.49	42.6	64.9	48.4	48.0
	1996–2005	5.45	33.4	4.05	24.8	77.49	78.97	63.2	114.7	48.0	48.6
	2006–2015	5.02	30.8	3.41	20.6	79.14	80.74	121.8	207.8	48.7	50.2
$D_{1.5}\ T_{10/3}$	1976–1985	4.88	29.9	4.56	28.0	75.98	71.96	23.0	27.6	47.8	45.9
	1986–1995	4.02	24.5	3.38	20.3	71.39	67.36	27.8	29.7	45.5	42.7
	1996–2005	3.49	21.1	2.67	15.3	66.98	65.41	29.9	38.1	42.5	41.0
	2006–2015	3.03	18.0	2.14	11.2	65.26	63.83	39.2	50.0	40.9	40.4
$D_{2.1}\ T_{10/3}$	1976–1985	5.18	31.8	4.79	29.4	77.75	77.27	25.4	39.5	48.2	48.2
	1986–1995	4.53	27.8	3.75	22.8	77.10	76.50	41.1	61.9	48.1	47.5
	1996–2005	4.19	25.6	3.12	18.6	76.50	78.03	65.8	110.1	47.4	47.9
	2006–2015	3.86	23.5	2.63	15.0	78.22	79.86	116.9	200.3	48.1	49.5
$D_{1.5}\ T_{10/7}$	1976–1985	4.55	27.9	4.26	26.1	75.98	71.75	23.0	27.3	47.8	45.8
	1986–1995	2.63	15.0	2.22	11.9	71.07	65.97	27.2	26.1	45.5	42.3
	1996–2005	1.56	neg.	1.20	neg.	65.50	62.85	25.9	27.6	41.9	39.8
	2006–2015	.92	neg.	.66	neg.	62.59	60.18	27.8	26.4	39.7	38.5
$D_{2.1}\ T_{10/7}$	1976–1985	4.84	29.7	4.47	27.4	77.75	77.04	25.4	39.0	48.2	48.2
	1986–1995	2.97	17.5	2.47	13.8	76.74	74.93	40.4	57.1	48.1	46.9
	1996–2005	1.87	neg.	1.41	neg.	74.81	74.98	59.6	94.7	46.8	46.6
	2006–2015	1.18	neg.	.82	neg.	75.02	75.29	100.0	161.7	46.6	47.3

course, the appropriate planning strategy is to continually update estimates in table 4 as a basis for future decisions.

Impact of R *on Farming Economy*

Rates of return on *R* investment cannot be viewed in isolation from their impact on the farming economy. Other things equal, greater *R* outlays mean lower farm income and prices received relative to prices paid (parity ratio). An "equilibrium" rate of return may be judged unacceptable if the productivity gains generated required unduly large outmovement of conventional farming resources in the face of a low parity ratio and farm income. In all scenarios if demand increased by more than 1.5% annually, the measures of parity and real net farm income indicate that the farming industry would be better off than in the case of 1.5% increases in demand, regardless of the rate of increase in dollars invested in *R* (table 4).

The possible trauma to farmers of adjusting the usage of conventional inputs—fertilizer, feed, seed, labor, etc.—to advances in technology is of concern. Since 1920, the volume of aggregate conventional production inputs has not changed markedly. Farmers have adjusted to growth in productivity arising from investment in nonconventional inputs, although with difficulty at times. Implied average annual rates of decrease in conventional inputs from 1975 to 2015 in scenarios with demand increasing at the standard 1.5% rate are as follows: .40% (T_3), .43% ($T_{10/3}$), and .55% ($T_{10/7}$). These downward adjustments in conventional inputs of about 0.5% per year with attendant problems for farmers must be balanced against efficiency gains. If it is deemed desirable to have no downward adjustments in production inputs, then any of the rates of increase in *R* proposed in this study is acceptable as long as demand for farm products increases at a rate faster than 1.5%.

Summary and Conclusions

The analysis addresses each objective of this study with the following conclusions:

(*a*) Rates of return in historic perspective aver-

age 50% on agricultural production-oriented research and extension (R) for the 1939–48 period, declining to 35% for the 1969–72 period based on a 16-year lag between R input and total obsolescence of the output from that input.

(b) Projected rates of return on alternative levels of investment for 1976 to 2015 range from a high of 39% for the slowest R change considered (T_3) to negative for later years with the highest rate of increase in R ($T_{10/7}$). Each dollar invested in R is projected to result in $5.62 of output in the 1976–85 period, $4.39 in the 1986–96 period, $3.46 in the 1996–2005 period, and $2.78 in the 2006–15 period using baseline projections of $D_{1.5}T_3$. The R investments promise to be a continuing low-cost source of additional farm output if their level of use is appropriately adjusted over time.

(c) If demand for farm output grows faster than the baseline 1.5% per year, then terms of trade (parity ratio), income and conventional input adjustments pose no apparent hardships for farmers as long as R outlays increase 10% per year or less from 1976 to 1980 and 3% per year thereafter. But slow rates of growth in demand coupled with rapid increases in R pose potentially severe economic hardships for farmers.

(d) On the basis of this study, incremental R outlays required to drive the rate of return to near 10% on investment are as follows: (*i*) If demand is expected to grow at a slower rate than 1.5% annually, increase real R by 3% per year, the historic average rate of increase. (*ii*) If demand is expected to grow 1.5% annually, increase real R by 10% for four years and at a real rate of 3% per year thereafter. (*iii*) If demand is expected to grow at a faster rate, increase real R by 10% per year for four to five years, then reduce the rate of increase to 3 to 5% per year. In each of the above cases, the payoff from increased R should be monitored from year to year to determine appropriate deviations from the above broad guidelines.

Limitations and Implications for Further Research

Although the R^2's of the model employed are over .99 and standard errors of estimates are small for equations predicting productivity, projections become quite unreliable for extended periods into the future. Productivity data have recently been revised and have been scrutinized for possible improvements, but problems in the series remain, such as failure to account adequately for changes in quality of inputs and output. The NIRAP model is also continually being refined, and future changes in the model undoubtedly will cause projections to be altered. Weather cycles and other unpredicable contingencies such as war, oil embargoes, breakthroughs in technology, could also markedly shift outcomes.

Actual rates of inflation above the 4% rate assumed to hold throughout the period of analysis would change the rate of return. Detailed projections on expected returns on R by commodity, region, and other disaggregations would be helpful, but are beyond the resources available for this study (see Eddleman). Rates of return computed in this study could be divided by 1.22 (Evenson's adjustment factor) to correct for private R investment, but that adjustment is probably too low for future years. More information on the influence of private research and other factors that influence rates of return would be useful. Control theory applied to determination of an optimal R investment path could provide helpful insights.

[*Received November 1977; revision accepted July 1978.*]

References

Board on Agriculture and Renewable Resources, Commission on Natural Resources, National Research Council, National Academy of Sciences. *World Food and Nutrition Study: Enhancement of Food Production for the U.S.* Washington, D.C., 1975.

Cline, Philip L. "Sources of Productivity Change in United States Agriculture." Ph.D. thesis, Oklahoma State University, 1975.

Cline, Philip L., and Yao-chi Lu. "Efficiency Aspects of the Spatial Allocation of Public Sector Agricultural Research and Extension in the United States." *Reg. Sci. Perspectives* 6(1976):1–16.

Eddleman, B. R. "Economic Evaluation of Investments in Agricultural Research." Mimeographed. Mississippi State University Agr. and Forestry Exp. Sta., 1978.

Evenson, Robert E. "The Contribution of Agricultural Research and Extension to Agricultural Productivity." Ph.D. thesis, University of Chicago, 1968.

Griliches, Zvi. "Research Costs and Social Returns: Hybrid Corn and Related Innovations." *J. Polit. Econ.* 66(1958):419–31.

———. "Research Expenditures, Education, and the Aggregate Agricultural Production Function." *Amer. Econ. Rev.* 54(1964):961–74.

National Research Council, National Academy of Sciences. *World Food and Nutrition Study: Interim Report,* Washington, D.C., 1975.

Peterson, Willis. "The Returns to Investment in Agricultural Research in the United States." *Resource Allocation in Agricultural Research*, ed. Walter Fishel, pp. 139–62. Minneapolis: University of Minnesota Press, 1971.

Tweeten, Luther. *Foundation of Farm Policy*. Lincoln: University of Nebraska Press, 1970.

———. "Formulating a National Food Policy for the Next Decade." *Food Information System:* Hearings before the Technology Assessment Board of the Office of Technology Assessment, 94th Cong., 1st and 2nd Sess., 10 Dec. 1975, pp. 209–25.

U.S. Department of Agriculture. *Changes in Farm Production and Efficiency*. ERS Statist. Bull. No. 561, 1976.

Potential for Increased Income on Small Farms in Appalachian Kentucky

Fred J. Stewart, Harry H. Hall, and Eldon D. Smith

Impoverished farmers still exist in the United States, especially in certain insular areas such as Appalachia (National Advisory Commission on Rural Poverty). These farmers tend to be older and poorly educated, the residual from migration of the young and better educated to urban areas over the past thirty to forty years; their farms tend to be small and unproductive. Even if these farmers had marketable skills, local opportunities for off-farm employment are limited.

Assuming that society will make some effort to aid impoverished farmers, this paper examines whether aid can best be applied to improve their productive capabilities or to provide direct assistance in the form of transfer payments and income-in-kind (medicaid, food stamps), as now. Four eastern Kentucky counties (Jackson, Lee, Owsley, and Wolfe) are the subject of the study. In 1974, 57% of the farms in this four-county area had gross sales less than $2,500 and 79% had sales less than $5,000; 66% of the farmers were over age 45. In 1970, the entire population was classified as rural, with 37% living on farms. The unemployment rate was 11.5%; and 54% of the families had incomes below $3,200, the official poverty level (USDC 1971, 1976).

Even if off-farm jobs were available, for older men with educational deficiencies to leave their homes and adjust to new work environments imposes potentially severe psychological stresses. Thus, if in society's judgment the incomes of these farmers are unacceptably low, the principal viable alternatives for improving incomes may be either permanent public assistance or increased farm earnings. A first step in evaluating these alternatives is to estimate the possible increases in farm incomes, i.e., to identify the practical upper bound on farm income. The main body of this paper addresses this first step. The paper concludes with a partial evaluation of this evidence in the light of experience with agricultural extension programs and institutional data on such things as tax structures. For these purposes, a "low income farmer" is defined as a full-time (working fewer than 100 days annually off the farm) operator under 65 years of age whose gross farm sales are less than $5,000. A survey of 342 operators in the four-county area identified 102 (29%) in this category.

Fred J. Stewart is an economist with the Economics, Statistics, and Cooperatives Service of the U.S. Department of Agriculture, stationed at the University of Florida, Gainesville. Harry H. Hall and Eldon D. Smith are, respectively, associate professor and professor of agricultural economics, University of Kentucky, Lexington.

The research on which this paper is based was conducted at the Kentucky Agricultural Experiment Station as Hatch Project No. 98 and is published with the approval of the director as Journal Article 75-1-114.

The authors acknowledge helpful comments from Neil Cook and from anonymous reviewers on an earlier draft.

Characteristics of Low Income Farms and Their Operators

Estimating the potential for increased incomes required that current incomes and enterprises be established. The survey identified certain physical and educational attributes of the farm operator and his family, incomes, enterprises, and available land and equipment resources. Information on management practices used in crop and livestock enterprises was collected to set up budgets reflecting the existing situation.

From the interviews, two distinct types of farms were identified. The first used mainly tractors for plowing, discing, cultivating, and hauling. The second, generally smaller in land resources, used either animals (mules) or custom operators to do these jobs. When the sample farms were stratified by power source, the differences between the two strata were statistically significant for several characteristics (table 1). These differences led to our decision to form two programming models, one for each stratum. Coefficients for various enterprises reflected different resource requirements as a result of the type of power. Only the results of the tractor-power model are reported here. A complete discussion can be found in Stewart, Hall, and Smith.

In general, table 1 indicates that these operators work with small land and labor resource bases. Operators using tractor-power tend to be younger and have larger amounts of family labor, especially during the summer months. The primary sources of income are tobacco and beef cattle.

Income Potentials

Linear programming was used to determine the potential for increasing incomes when the land and labor resources were limited to observed levels. A

Table 1. Selected Characteristics of the Sample Population

	All Farms	Tractor-Power Farms	Animal-Power Farms
Labor			
Operators	102	43	59
Operator age	47.1	44.4	49.2[a]
Physical ability (%)[b]	81	85	79
Total family labor supply, June–August based on 40-hr. week (hrs./week)	62.8	67.5	59.4[a]
Land			
Continuous crop land (acres)	4.1	4.1	4.1
Rotation crop land (acres)	5.5	9.3	2.7[a]
Open hay and pasture land (acres)	15.0	20.0	11.3[a]
Practices			
Tobacco grown (pounds)	3197	3832	2738[a]
Leased tobacco allotment (acres)	0.8	0.9	0.6[a]
Cwt. tobacco fertilizer (5–10–15/acre)	24.4	23.1	25.3[a]
Corn (acres)	2.6	3.2	2.2[a]
Corn yield (bu./acre)	60.5	64.9	56.6[a]
Dairy and beef cattle income/year ($)	1056	1483	703[a]

[a] Significantly different from the Tractor-Power Group at the .05 level.
[b] Based on the operator's rating his physical ability compared to that of a 30-year-old operator.

representative farm was used with resources equal to the average of all tractor-powered farms. Coefficients for competing enterprises reflected observed conditions as determined from survey data. Thus, only those enterprises observed on survey farms were included in the programming models.[1] Other, more unusual and possibly more profitable, enterprises could have been used in the models, but we assumed that institutional or market barriers, operator ignorance of possibilities, or operator preferences eliminated such enterprises from the set of alternatives available to operators in the short run.

Existing versus Improved Practices

In addition to the potential for higher incomes from more efficient use of resources under existing practices, we were interested in the effects of improved management on incomes and enterprise combinations. The potential increase in income and efficient combination of resources and enterprises for three capital and two management levels is shown in table 2. The most striking differences between the observed enterprise mix and Model 1-E (existing management practices and unlimited capital) are (*a*) a $1,900 (71%) increase in income, (*b*) increased vegetable production, and (*c*) substitution of dairy cows for beef cattle and feeder pigs. Vegetable enterprises accounted for most of the increase in income and used most of the cropland. An operator's decision not to expand vegetables from the observed level to the level in Model 1-E results in his foregoing of more than $1,600 income.

An even greater increase in income is possible with improved management, which was based on comparisons of published data and on discussions with county agents and University of Kentucky specialists. It was felt that this level of management was attainable by the majority of operators interviewed. With improved management, income increased $3,909 (147%) in Model 1-I over the observed income. Most of the increase is the result of expansion in vegetables and feeder pigs. Because of the larger feeder pig enterprise, nonland capital increased $15,000 over the observed level. Nonland capital refers to out-of-pocket expenses for fertilizer, feed, hired labor, and materials for various enterprises. Adoption of improved practices and optimal enterprise combinations results in a $2,009 increase in income for Model 1-I over Model 1-E.

Capital As a Constraint

To test the limiting effect of capital on income, two models were used with restricted capital supplies.

[1] The frequency of occurrence among surveyed operators and prevailing product prices for the enterprises included in the model were

Enterprise	Observed Frequency (%)	Product Price ($)
Tobacco	98	.79/pound
Tobacco on shares	52	.79/pound
Corn	63	1.43/bushel
Hay	59	.80/bale
Cucumbers	9	2.00/bushel
Peppers	11	70.00/ton
Dairy (manufacture milk)	3	5.00/cwt.
Beef cattle	26	.38/pound
Swine	9	.375/pound

Table 2. Observed Mean Resources, Income, and Enterprise Mix Compared with Optimal Enterprise Mix with Existing and Improved Practices and Three Levels of Capital

		Existing Practices			Improved Practices		
	Observed Enterprise Mix	1-E Unlimited Capital	2-E $1000 Capital Limit	3-E $3000 Capital Limit	1-I Unlimited Capital	2-I $1000 Capital Limit	3-I $3000 Capital Limit
Net income ($)	2,662	4,562	3,944	4,542	6,571	5,493	6,206
Enterprise levels							
Tobacco owned (acres)	0.8	1.0	1.0	1.0	0.8	0.8	0.8
Tobacco on shares (acres)	0.9	0.9	0.9	0.9	0.8	0.8	0.8
Corn (acres)	3.1	0.0	0.0	0.0	0.0	0.0	0.0
Hay (acres)	9.2	13.6	7.8	14.2	15.0	6.9	20.4
Cucumbers (acres)	0.1	2.0	2.6	2.0	1.5	2.8	2.2
Peppers (acres)	0.2	3.7	3.6	3.8	3.8	3.7	4.5
Total crops (acres)	14.3	21.2	15.8	21.9	21.9	15.0	28.7
Dairy cows	0.0	6.1	0.0	5.5	0.0	0.0	0.5
Beef cows	3.8	0.0	0.0	0.0	0.0	0.0	0.0
Sows	0.5	0.0	0.0	0.0	44.0	0.0	5.0
Hay sold (tons)	6.5	12.9	16.3	15.6	37.3	17.0	49.0
Tobacco leased (lb.)	0.0	443.0	443.0	443.0	443.0	443.0	443.0
				($)			
Operating capital	745	1,394	1,000	1,402	4,276	1,000	2,016
Animal capital	616	1,145	0	1,043	4,088	0	680
Building capital	0	609	0	555	9,020	0	304
Total nonland capital	1,361	3,148	1,000	3,000	17,384	1,000	3,000

The first restricted capital to $1,000. The second allowed $1,000 capital increments until average income from the increment was less than $100, which occurred with $3,000 of capital.

Results in table 2 show that when capital is limited, maximum income requires emphasis on crops rather than livestock. With the high productivity of even small amounts of additional capital under both existing and improved practices, it is not clear whether the observed use of limited amounts of capital is the result of external capital rationing by lending institutions or internal capital rationing by farm operators.

Removing Tobacco-Allotment Restrictions

Current regulations on Burley tobacco prohibit movement of leased allotments across county lines. To examine the effect of changes in these regulations, Model 4 assumes that a farm operator could lease unlimited tobacco allotment at 20¢ per pound. This situation might occur if current restrictions were removed and operators in areas with excess labor could rent allotments from labor-scarce areas. Model 4 further assumes that all leased allotment would be used on the operator's land, and that he would be required to build barn space for any tobacco that could not be housed in his existing barn. Nonland capital is restricted to $3,000.

Models 4-E and 4-I (table 3) show that with limited capital, the gains from unlimited tobacco allotment leasing are not large. Increased tobacco production from allotment leasing offers opportunities for increased incomes only if capital is available at levels much higher than currently used. Even if unlimited tobacco leasing is not possible, either because of regulation or operator preference, loss of income is not particularly great because vegetable and livestock enterprises are profitable alternatives when capital supplies are limited.

Vegetable Enterprises

In eastern Kentucky, both cucumbers and peppers are grown under contract to processors who sell their processed product in the national market. Hence, increased production in this area only would have little effect on prices. The principal price risk to farmers could be getting a contract in the first place, but since 1972, processors of both crops have been unable to sign as many contracts as they wanted, despite raising prices by at least 50%.

Contracting removes much of the price risk for farmers but not the risk of yield variability. In case of crop failure, a farmer's out-of-pocket loss is relatively small—$140 per acre for cucumbers and $75 per acre for peppers in 1977. Serious yield reductions substantially reduce his income from the expected level, however. Sensitivity analysis indicates that yield reductions of up to 45% under existing practices or up to 50% under improved practices affect the optimal levels of vegetables relatively little (table 4). The low yields used under existing practices for both vegetable enterprises were be-

Table 3. Comparison of Income and Enterprise Mix with Restricted and Unrestricted Tobacco Allotment Leasing, $3,000 Capital Limit, Existing and Improved Practices

	3-E Restricted Tobacco Allotment Leasing	4-E Unrestricted Tobacco Allotment Leasing	3-I Restricted Tobacco Allotment Leasing	4-I Unrestricted Tobacco Allotment Leasing
Net income ($)	4,542	4,780	6,206	6,267
Enterprise levels				
Tobacco owned (acres)	1.0	2.0	0.8	1.5
Tobacco on shares (acres)	0.9	0.9	0.8	0.8
Hay (acres)	14.2	21.4	19.5	21.3
Cucumbers (acres)	2.0	1.9	2.2	2.1
Peppers (acres)	3.8	3.6	3.6	4.1
Total crops (acres)	21.9	29.8	26.9	29.8
Dairy cows	5.5	0.0	0.5	0.0
Sows	0.0	0.0	5.0	0.0
Hay sold (tons)	15.6	44.5	49.0	52.9
Tobacco leased (lb.)	443.0	2,443.0	443.0	2,196.0
	($)			
Operating capital	1,402	2,000	2,016	2,124
Animal capital	1,043	0	680	0
Building capital	555	1,000	304	876
Total nonland capital	3,000	3,000	3,000	3,000

yond the 99% confidence limits for the mean estimated from survey data. Thus it appears that, among the enterprises considered, vegetables provide the most reliable income available, after tobacco, even at yields considerably lower than expected.

For comparison with the yields specified in table 4, the quantities purchased, prices and mean yields at seven pepper receiving stations in eastern Kentucky for the past three years were

Year	Tons Purchased	Contract Price/ton	Mean Yield (tons/acre)
1975	7,867	$100	4.15
1976	5,320	105	4.60
1977	5,194	105	4.30

Comparable information is not available for cucumbers. For 1977, the data were

Year	Cwt. Purchased	Contract Price/cwt. (average grade = 2)	Mean Yield (cwt./acre)
1977	8,113	$7.50	180

According to cucumber processors, quantity purchased and acreage under contract has increased each year since 1970.

Policy Implications—Benefits and Costs

Under conditions faced by low income farmers in eastern Kentucky, incomes can be improved by

Table 4. Income and Enterprise Mix for Low and Expected Vegetable Yields, Existing and Improved Practices, $3,000 Capital Limit

	Existing Practices		Improved Practices	
	Low Yield[a]	Expected Yield[b]	Low Yield[c]	Expected Yield[d]
Net income ($)	3,641	4,609	4,337	6,206
Tobacco (acres)	1.9	1.9	1.6	1.8
Hay (acres)	19.0	18.2	17.5	17.5
Cucumbers (acres)	2.2	1.9	2.5	2.2
Peppers (acres)	.9	4.4	3.9	4.5
(Total vegetables)	(3.1)	(6.3)	(6.4)	(6.7)
Sows	0.0	0.0	5.0	5.0
Dairy cows	5.8	4.4	0	0.5

[a] 3 tons per acre for peppers; 75 cwt. per acre for cucumbers.
[b] 5.5 tons per acre for peppers; 139 cwt. per acre for cucumbers.
[c] 4 tons per acre for peppers; 100 cwt. per acre for cucumbers.
[d] 8 tons per acre for peppers; 200 cwt. per acre for cucumbers.

selecting more profitable enterprises, improving technical management, or both. In some cases, additional capital will be required; in others, managerial capabilities must be improved. More capital is required if incomes are to be maximized, but substantial income increases are possible even with existing amounts of capital. Similarly, more leased-in tobacco would increase income potentials, but at prices current at the time of the study, vegetables were good substitutes for tobacco, and probably would be in the future. Any program to improve farm incomes presumes a knowledge of (*a*) the characteristics of an effective program, and (*b*) the benefits and costs of such a program.

Program Requirements

Ninety-five percent of the operators interviewed said they would use more capital if they could make more money by doing so, and 89% said they would borrow money to expand their farm operations if it appeared profitable to do so. Fifty-two percent of the operators planned to expand their farming operations. Furthermore, the income potentials indicated by this study assume technologies that are either available or now in use and use labor that already exists on these farms. It appears probable, therefore, that lack of information about the opportunities for improving incomes rather than lack of motivation is the primary problem. However, any policy or program aimed at educating low income farmers must deal with the following problems.

The average age of operators interviewed in this study was 47. The discounted value of an increased income stream for the average farmer from now until retirement must be compared to the cost of programs to bring about income improvements. For older operators, the costs of programs that would produce small income increases for a short time before retirement may not be justifiable on the basis of benefit and cost alone. For example, the present value of the $1,900 increase in Model 1-E over ten years at an 8% discount rate is $13,769.

Average education of operators was 6.5 years. With low educational levels, more efforts may be required to achieve higher levels of managerial proficiency, especially if reading and mathematical skills are required to use appropriate technologies.

The majority of the population interviewed is not reached by traditional educational agencies. Only 12% of the operators interviewed contacted the county agricultural extension agent in the year preceding the survey, and most of these were for a specific pepper blight problem.

Some practices widely accepted on most commercial farms were still not used on many farms in this study. For example, only 15% of the farm operators used soil tests to check soil fertility in the previous year, while 51% used open-pollinated rather than hybrid seed corn.

Adherence to outdated practices is perhaps the biggest obstacle to increased incomes through improved enterprise selection. Most operators chose to raise what tobacco they could as their sole cash crop, rather than try the relatively new vegetable enterprises.

Costs and Benefits

Estimating the benefits and costs of a program to improve the incomes of low income farms is complicated by a variety of factors. The length of time such a program would have to run is also difficult to assess. The rather simple economic structure of the average subsistence farm, however, suggests that a relatively intensive educational effort would cost no more per farm than the program for farms cooperating in the Farm Analysis Groups of the Kentucky Cooperative Extension Service. In 1974, the costs per farm for this latter program, including the cost of staff support at the University of Kentucky, averaged less than $350. The potential annual gains to low income farms in eastern Kentucky from optimal enterprise selection and improved management are more than four times this amount.

Public costs for families in poverty include costs of free services and income transfers plus the foregone taxes they would pay if they were self-supporting. Average earnings for farmers in the survey of this study were well below the poverty standard ($2,622 as compared to the standard for a family of four of $3,200). We have no information about the extent of public assistance to farmers in this group, but virtually all are eligible for at least food stamps. State and federal income taxes generated from increased incomes as well as elimination of food stamp dependence could substantially offset or even match the cost of managerial assistance. For a farm family of four, with no other source of income filing a joint return with the standard deduction, the 1970 federal income tax would have been $350 on the net income in Solution 2-I (IRS).

It is not clear exactly how much can be achieved by extension efforts among small-scale farmers nor exactly what the public benefits would be. The examples cited, however, suggest that with even a modest level of achievement such efforts may be among the most cost-effective antipoverty programs. Moreover, such programs would have the distinct administrative advantage of requiring only minimal control over expenditures and the psychological advantage to the farmers involved of making them more nearly self-supporting.

This study shows that the potential for increasing income exists. The possibility of achieving this potential needs to be explored in greater depth, probably through experimental or pilot technical assistance programs. The experience with similar programs aimed at low income farmers in Tennessee, Missouri, Texas, and Virginia could serve as guides (Comer and Woodworth, West, Strickland and Soliman, and Orden, respectively).

[*Received December 1976; revision accepted June 1978.*]

References

Comer, Sammy, and Roger Woodworth. *Improving Incomes on Limited Resource Farms in South Central Tennessee*. Tennessee State University Bull. 36, 1976.

National Advisory Commission on Rural Poverty. *The People Left Behind*. Washington, D.C., 1967.

Orden, David R. *An Analysis of Socio-Economic Characteristics, Resources, Management Practices, and Productivity of Small Farm Operators in Floyd and Brunswick Counties, Virginia*. M.S. thesis, Virginia Polytechnic Institute and State University, 1977.

Stewart, Fred J., Harry H. Hall, and Eldon D. Smith. *Potential for Increasing Net Incomes on Limited-Resource Farms in Eastern Kentucky*. University of Kentucky Agr. Exp. Sta. Res. Rep. No. 24, May 1976.

Strickland, Cecil L., and Mostafa Soliman. *Nonprofessional Aides in Agriculture, an Evaluation of a Program in Cooperative Extension Education for Small Farm Families*. Prairie View A&M University Bull. B-1165(PV), 1976.

U.S. Department of Commerce, Bureau of the Census (USDC 1976). *U.S. Census of Agriculture, 1974*. Preliminary County Reports. Washington, D.C., 1976.

———. (USDC 1971). *1970 U.S. Census of Population*. Washington, D.C., 1971.

U.S. Department of the Treasury, Internal Revenue Service (IRS). *Your Federal Income Tax*. Washington, D.C., 1971.

West, Jerry G., Van R. Harrold, K. C. Schneeberger, and Lionel Williamson. *Missouri Small Farm Program: An Evaluation with a Control Group*. University of Missouri Pub. SR176, 1975.

Some Fiscal Impacts of Farmers Home Administration Home Loan Activity on a Rural County

James T. Lindley and Patricia A. Wiseman

The fiscal impact of a low income housing program on a locality is of concern to program administrators and local officials alike. Local officials often oppose low income housing on the grounds that it is fiscally detrimental to their jurisdiction. One program is sponsored by the Farmers Home Administration of the United States Department of Agriculture (FmHA). FmHA provides subsidized and nonsubsidized, new and existing home loans, as well as loans for rehabilitation in areas designated rural. FmHA financing requires no down payment and closing costs are low. The usual government constraints on loan limits and maximum incomes apply. Interest credit based on income and family size can reduce interest rates on loans to as low as 1%, thus providing a significant subsidy for some persons in the program (Catalogue of Federal Domestic Assistance). In this paper we make an attempt to determine some fiscal impacts of FmHA-financed housing in one rural county in Virginia.

Specifically the paper will examine (*a*) the percentage of borrowers who are native (residing in the county when applying for the loan), (*b*) the real estate assessment of natives before and after obtaining a FmHA mortgage, (*c*) the tax delinquency rate of FmHA borrowers relative to the rest of the tax-paying population, (*d*) the impact of interest credit mortgagors (subsidized through lower interest rate) relative to nonsubsidized mortgagors, and (*e*) comparison of per capita real estate taxes paid by FmHA borrowers as compared to the average per capita real estate taxes in the county.

Methodology

The rural county chosen for this study has 550 square miles, is centrally located between two SMSAs and is near a medium-sized city (under 50,000 population). A major source of income for residents is farming. Lumber and metal industries account for most of the manufacturing employment, and a number of residents are employed at federal installations.

Data were collected from the applications of 480 successful FmHA borrowers in the county from 1965 to 1975 inclusive. Information obtained from the original mortgage application was supplemented by information from tax records and real estate assessments. Real estate assessments were collected from each member of the sample for the year immediately prior to the year in which the mortgage was obtained to determine the change in assessment of the sample. Property tax delinquency data were gleaned from the published delinquent tax lists for each year of the study. A person was listed as delinquent for the particular year if his taxes were delinquent by even one day regardless of how soon they were paid after the due date. Material regarding assessment/sales ratios and local levies were gathered from annual reports of the Virginia Department of Taxation.

Results

It is evident from the projected growth rate of the county (1.1% annually) that there is not a large net influx of persons. Nevertheless, it is possible for a subsidy program to attract low income persons into an area in disproportionate numbers. However, because FmHA operates statewide in all areas considered rural, the possibility of that phenomenon diminishes. In the sample, 80% of all loans were given to original residents. Of the remaining 20%, approximately half had originally resided in the county but had taken up other residency (usually in one of the surrounding SMSAs) and were returning to the county. Approximately 25% of the immigrants had previous real estate assessments in the county indicating ownership of land and/or dwellings prior to obtaining a mortgage. As a benchmark of comparison, the gross immigration figure for the county for the period of 1965 through 1970 was 14% of the county population (Bureau of Census, p. 128). During the same period, the immigration rate for persons residing in FmHA-mortgaged dwellings was 1% of the sample population. For the period 1970 through 1975, the rate for persons in FmHA-mortgaged dwellings was 24% of the sample. Immigrants obtaining mortgages had significantly higher incomes, larger mortgages, and included a greater percentage of whites than did natives in the sample.

James T. Lindley is staff director, and Patricia Wiseman is research assistant, Revenue Resources and Economic Commission, Commonwealth of Virginia.

A portion of this study was done while the authors were with the Office of Housing, Commonwealth of Virginia.

The authors wish to thank E. A. Ragland for assistance in acquiring data, J. Moser for computer assistance, and an anonymous referee of this *Journal* for constructive comments. Responsibility for errors remain with the authors.

Immigrants had no more children per family than natives and thus would not impose a disproportionate burden on schools. Immigrants were also less tax delinquent than natives, possibly reflecting the lower incomes of natives in the sample, although familiarity with the local property tax system cannot be ruled out as a factor in natives being delinquent more often. Higher mortgage amounts likely reflect that immigrants more often financed the lot along with the house since they owned land significantly less often.

Real Estate Assessment

To determine the impact on property tax revenues, real estate assessments were examined. As noted earlier, approximately half of the immigrants had at one time resided in the county and 25% of them owned real estate prior to obtaining a FmHA mortgage. The average assessed valuation for immigrants was $8.47 per mortgagor. For natives, 50% owned property prior to acquiring a mortgage making the average assessed valuation for that part of the sample $72.15. For the total sample the average assessed valuation per mortgagor was $59.15. The per capita valuation for the county ranged from $967.21 in 1965 to $2,718.58 in 1975. It is evident that there was little contribution in real property taxes by those in the sample prior to acquiring a mortgage.

Because of the uneven and sporadic assessment practices that existed throughout much of the period, assessment values were estimated for the sample rather than by using land books. Since FmHA requires no down payment, the loan amount was considered to be the market value of the house. To the extent that borrowers owned land prior to acquiring a mortgage, the loan amount is an understatement of total value. The assessment sales ratio provided by the Virginia Department of Taxation was applied to the loan amount (market value) and the resulting assessed valuation was multiplied by the tax rate for the year. Taxes were calculated for the mortgagor (per unit) and on a per capita basis using the number of persons in the household.

With the above information, it is possible to determine the fiscal impact of the FmHA program on the county. For the years 1965 through 1975, the average per capita tax figures for real property taxes in the county and for mortgagors are in table 1. It can be seen that the disparity between average for the county and mortgagors increases over time. Another comparison is the per capita tax figures when the value of land is excluded from the assessment. Excluding land excludes all of the timber and farm land along with lots for dwellings. As shown in column 3, the per capita figures are much closer when using this measure. However, since not all of the FmHA mortgagors owned land prior to applying for a loan, the comparisons are not of the same absolute magnitude. The comparisons do point out that FmHA mortgagors are much closer to the average home owner in terms of real estate tax revenues than it would appear on the surface.

Table 1. Average Real Property Taxes Per Capita

Year	Non-FmHA Mortgagors	FmHA Mortgagors	Non-FmHA Mortgagors Improvements Only
		($)	
1965	20.29	15.47	12.44
1970	40.13	17.19	16.02
1975	54.03	20.67	23.43

Left unanswered is the charge that immigrants acquiring mortgages constitute a fiscal loss to the county because it would have to expand services to accommodate these additional people. There is an indirect way to test this proposition. It is possible to determine if the increased tax revenue from native FmHA borrowers more than compensates for the difference in the per capita taxes paid by the average person in the county and the per capita taxes paid by immigrant borrowers. Admittedly, this measure is not the same as comparing the marginal increase in costs of immigrants with the marginal increase in revenue. The marginal cost of an additional person, while a desirable figure, could not be determined for the county.

To compute the above differences, the average per capita levy in the county is multiplied by the number of persons in the FmHA households immigrating into the county and totaled for the group. From this is subtracted the amount of taxes the immigrant group pays. The net negative figure represents the additional amount that immigrants would be paying if they were average taxpayers in the county. This negative result can then be compared to the difference between what native mortgagors paid in taxes before acquiring a mortgage and what they paid after. Since natives are already using all of the services in the county, they do not constitute an increase in expenses for the county. If the increased amount of taxes paid by native mortgagors is greater than the net loss on immigrants, the county's average per capita real estate tax will have increased. Although not constituting a proof that homeowners pay or do not pay their own way, it is an indication that the county may be in a better fiscal position. The county's per capita real estate taxes did increase for the period 1965–75 (table 2).

It is recognized that the money to pay greater amounts in property taxes, and possibly higher shelter costs, must be diverted from some other use or gained through additional labor effort. To the extent that the money comes from a reduction in other expenditures, there could exist a reduction in sales taxes collected for the local government. The effect of a reduction in consumption of nonshelter

Table 2. Total Taxes Paid by FmHA Borrowers

Year	Total Additional Taxes of Residents	Amount Total Taxes of Immigrants are below County Average Level
	($)	
1965	145	0
1970	1,787	0
1975	6,416	5,024

items is muted somewhat because approximately 35% of the income in the county is spent elsewhere.

Tax Delinquency

The tax delinquent portion of the sample was evaluated relative to that portion that was not tax delinquent. Tax delinquents as a group included a significantly smaller percentage of subsidized (interest credit) mortgagors, thus eliminating tax delinquency as a negative factor against subsidized home ownership. Natives in the sample were more likely to be tax delinquent than immigrants, refuting claims that "outsiders" moving into an area were more likely to be tax delinquent than natives. Tax delinquents were more likely to have owned land at the time of their mortgage approval. Also tax delinquents in the sample had lower incomes.

Eighty-three percent of the mortgagors in the sample were not tax delinquent during the years under consideration, but for the year 1974, FmHA borrowers had a delinquency rate of 17% against a rate of 11% for the county as a whole.

Interest Credit

Forty-nine percent of the borrowers had interest credit loans and, as noted earlier, those borrowers were significantly less tax delinquent. Given that half of the FmHA borrowers are subsidized, it is important to the program that tax delinquency of the interest credit mortgagors not be a source of irritation to the county.

As would be expected, the subsidized group had lower incomes. However, their mortgage amounts were larger than those of their nonsubsidized counterparts. Subsidized mortgagors had a lower percentage of land ownership when making the mortgage and thus they financed the land along with the house more often than their nonsubsidized counterparts. Moreover, family size as well as income affects loan limits. Subsidized families had younger male heads of households, more children per household, and relatively fewer married heads of households. Indeed, it would be inconsistent with the nature of the program if the subsidized mortgagors did not exhibit a larger proportion of the above characteristics since the aim of the interest credit program is to benefit the disadvantaged.

Conclusions

In this paper an attempt has been made to explore the relationship between low income housing (FmHA) and the tax base in a rural county. It was found that 80% of the FmHA mortgagors were residents of the county and thus currently using county services. Approximately half of the immigrants had previously resided in the county at some time and 25% of the immigrants had previous real estate assessments in the county. Interest credit (subsidized) mortgagors were not any more tax delinquent than nonsubsidized mortgagors in the sample and the overall tax delinquency rate for the sample was about 6% higher than the county average. Taxes paid by the native portion of the sample increased by over thirty times as a result of acquiring a FmHA mortgage.

The difficult question of whether homeowners in the sample pay their own way [James, Mace, National Commission on Urban Problems] is not answered. What is answered is the question: Is the county fiscally worse off as a result of the FmHA home loan program? In this case it is not. One of the reasons that it was not worse off is that the program did not attract immigrants in numbers much different from the normal migration rates. If it had the results could be different. It is unlikely, however, that a uniform statewide program would encourage migration above normal. With that being the case, an increase in taxable wealth, subsidized by the federal government, should leave a county with greater tax revenues with which to provide the already existing services. The results of this study support that hypothesis.

[*Received February 1978; revision accepted July 1978.*]

References

James, Franklin J., Jr., and Oliver Duane Windsor. "Fiscal Zoning, Fiscal Reform, and Exclusionary Land Use Controls." *J. Amer. Inst. Planners* 42(1976): 130–41.

Mace, Ruth L., and Warren J. Wicker. *Do Single Family Homes Pay Their Way?* Urban Land Institute, Res. Monograph 15, Washington, D.C., 1968.

National Commission on Urban Problems. "Restrictive Zoning." *Housing Urban America*, eds. Jon Pynoos, Robert Schafer, and Charles W. Hartman. Chicago: Aldine Publishing Co., 1973.

U.S. Department of Commerce, Bureau of the Census.

Current Population Reports, Gross Migration by County: 1965 to 1970. Washington, D.C., Series P–25, No. 701, May 1977.

U.S. Office of Management and Budget. *1977 Catalogue of Federal Domestic Assistance*. Washington, D.C., 1977.

Virginia Department of Taxation. *Virginia Assessment Sales Ratio Study*. Richmond, Va., 1975.

A Routing Algorithm Using the Nearest-Neighbor Concept

M. C. Hallberg and W. R. Kriebel

The design of routes for delivery or assembly of goods or people and the associated problem of vehicle scheduling is a relatively new problem to be tackled by operations researchers although it has vexed decision makers in the business world since the invention of the delivery vehicle. The salient feature of the problem is that of finding the least-cost paths emanating from and terminating at a warehouse or depot over which one or more vehicles are to traverse in serving each of n customers. This is by no means a trivial problem given the service-oriented nature of today's economy, the congestion on highways and streets, and the present energy situation. Further, it is not easily resolved with traditional techniques of the operations researcher because of its "combinatorial" nature (see Hallberg and Kriebel).

The first researchers to tackle this problem appear to have been Garvin, Crandall, John, and Spellman. Their approach, however, relied on the use of linear programming which is not known to be particularly efficient (if feasible at all even with modern-sized computers) at solving "combinatorial" problems. They were able to generate optimal solutions, but only for routing problems of a size that had no practical significance. This work spurred others to investigate the problem and led to the work of Clarke and Wright, who developed a simple but effective heuristic approach that has proven in a variety of applications to yield "good," although not necessarily "optimal," solutions to routing problems of a practical size.[1]

In a recent application, we have isolated problems having certain unique characteristics for which the Clarke-Wright technique will often produce unacceptable (and clearly nonoptimal) results. While several authors have suggested modifications to improve upon the Clarke-Wright technique (see the review articles by Turner, Ghare, and Fourds, and by Golden, Magnanti, and Nguyen), none have dealt with the specific problem encountered here. In this paper we describe the nature of these uniquely structured problems, and outline a modification of the Clarke-Wright method which maintains the integrity of the basic procedure, ensures better (more nearly optimal) solutions for the class of problems described, and ensures no worse solutions for routing problems that do not have the structure of those described here.

The Problem Studied

In the application referred to, the subject firm was a large grocery distribution wholesaler in Harrisburg, Pennsylvania. The physical plant consists of a 250,000 square foot, one-story building having 220 floor positions or bays, arranged in a rectangular pattern throughout the warehouse, on which grocery items are inventoried. Individual orders to be filled and ultimately delivered to a loading dock on pallets are assembled on 70 cubic-foot capacity clamp-lift trucks that travel aisles of equal length through the warehouse, retrieving grocery items from appropriate floor positions or storage bays. A typical clamp-lift truck travels a total distance of one mile and clocks one and one-half hours in filling an order. If we treat floor positions as "customers" and the loading dock as the assembly point, we have a typical routing problem, the objective being to design routes through the available "road network" so as to minimize distance and hence energy usage, and cost.

The Clarke-Wright Solution

A somewhat unique structure is readily apparent in the problem just described—all "customers" are located on a grid network with equally spaced vertical and horizontal grid lines. Figure 1 exemplifies one such network. We illustrate the nature of the anomaly with the Clarke-Wright heuristic by using it to develop a single route emanating from the warehouse which traverses the node network shown in figure 1 (the vehicle must travel on the lines drawn in) such that all fourteen customers are visited and that the delivery vehicle subsequently

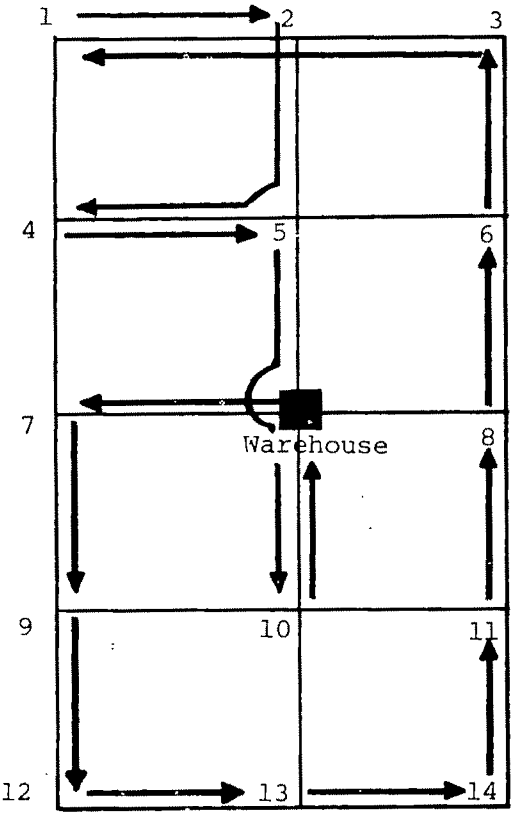
---

M. C. Hallberg and W. R. Kriebel are professors of agricultural economics at Pennsylvania State University.

Authorized for publication as paper number 5551 in the journal series of The Pennsylvania State University Agricultural Experiment Station.

The authors are indebted to Mr. Wolfgang Neitzel for assistance on the project that led to the ideas incorporated in this paper.

[1] A complete description of the Clarke-Wright technique as well as a discussion of its performance is contained in Clarke and Wright, Schruben and Clifton, and Hallberg and Kriebel. We assume in what follows that the reader has reviewed these or similar references so that he is thoroughly familiar with the Clarke-Wright algorithm. "Good" solutions here mean solutions superior to those developed by most other known methods, and, in particular, ad hoc methods employed by human dispatchers.



Note: Distance between any adjacent customers and between customers 5, 7, 8, and 10 and the warehouse equals one.

Figure 1. Clarke-Wright solution to hypothetical routing problem

returns to the warehouse. We want to develop a route which minimizes the distance traveled in accomplishing this task.

The first step is to construct a savings matrix that consists of elements $s_{ij} = d_{io} + d_{oj} - d_{ij}$, where s_{ij} is distance saved by linking customers i and j onto the same route as opposed to serving them on separate routes, $d_{io} = d_{oi}$ is shortest distance between warehouse and customer i, and d_{ij} is shortest distance between customers i and j. This matrix is shown in table 1 (only one-half of the matrix is shown because it is symmetric).

The second step is to arrange the elements of this matrix in descending order so as to facilitate route development. This we have done (ignoring all zero s_{ij}'s) as follows:

Customer i	Customer j	s_{ij}	Customer i	Customer j	s_{ij}
1	2	4	4	5	2
1	3	4	4	6	2
1	4	4	4	7	2
2	3	4	4	9	2
3	6	4	4	12	2
9	12	4	5	6	2
11	14	4	6	8	2
12	13	4	6	11	2
12	14	4	6	14	2
13	14	4	7	9	2
1	5	2	7	12	2
1	6	2	8	11	2
1	7	2	8	14	2
1	9	2	9	10	2
1	12	2	9	11	2
2	4	2	9	13	2
2	5	2	9	14	2
2	6	2	10	11	2
3	4	2	10	12	2
3	5	2	10	13	2
3	8	2	10	14	2
3	11	2	11	12	2
3	14	2	11	13	2

The final step involves determining the sequence of customers on the route by the procedure outlined by Clarke and Wright, starting with the largest saving coefficient arrayed and proceeding one by one until all customers are linked. (In order to specify the route completely, the zero s_{ij}'s must also be considered. We did not list them in the above array in the interest of conserving space.) This yields the route: Warehouse-7-9-12-13-14-11-8-6-3-1-2-4-5-10-Warehouse, which covers a distance of eighteen units.

The "Nearest-Neighbor" Solution

For reasons that will be obvious from a visual inspection of this route as traced on figure 1, our hypothetical client is not likely to be happy with our suggested route. The problem is, of course, due to the fact that there is obvious and unnecessary backtracking on a portion of the route. This, in turn, is due to the fact that there are ties in the

Table 1. Savings Matrix for Hypothetical Routing Problem

	Customers													
Customer	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	—	4	4	4	2	2	2	0	2	0	0	2	0	0
2		—	4	2	2	2	0	0	0	0	0	0	0	0
3			—	2	2	4	0	2	0	0	2	0	0	2
4				—	2	2	2	0	2	0	0	2	0	0
5					—	2	0	0	0	0	0	0	0	0
6						—	0	2	0	0	2	0	0	2
7							—	0	2	0	0	2	0	0
8								—	0	0	2	0	0	2
9									—	2	2	4	2	2
10										—	2	2	2	2
11											—	2	2	4
12												—	4	4
13													—	4

savings coefficients and we failed to deal with these ties adequately before beginning route development.

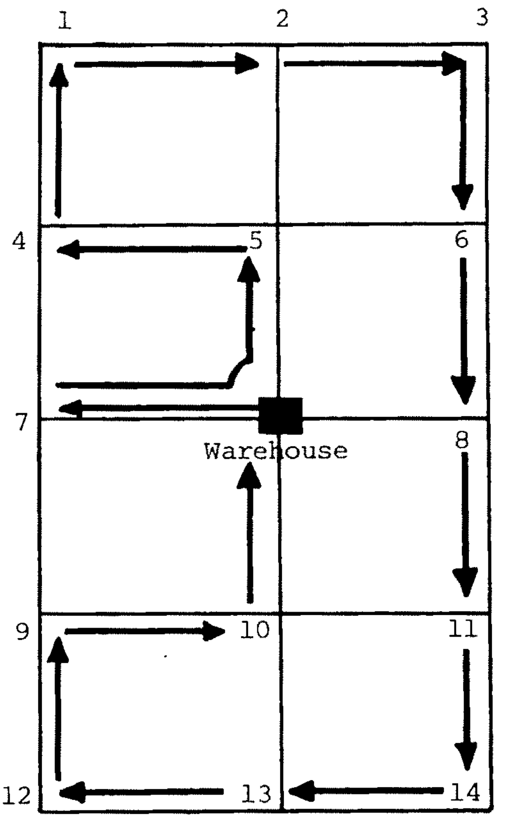
Clarke and Wright suggested that when ties occur in the savings coefficients, select at random from among the tied set. In our case we used a more systematic approach—we ranked the savings coefficients in descending order by systematically searching each row in turn, starting with the first. (One would like a systematic, rather than a random, procedure if for no other reason than to facilitate the development of an efficient computer code for the Clarke-Wright heuristic.)

The random approach will not necessarily yield results any worse than that of our more systematic approach, but by the same token it will not guarantee better results. Using the nearest-neighbor concept outlined below, we can guarantee better results for routing problems with a structure similar to that of our hypothetical problem. (As far as we are aware this concept has not been utilized before in the fashion we are proposing. Tyagi has used the nearest-neighbor concept in an attempt to group demand points into tours prior to developing routes with a traveling salesman algorithm.)

Note that if we have a choice of which pair of customers to link sequentially on the route, all else equal, it seems logical to link that pair who are nearest to one another. The logic of this is that it minimizes the possibility of temporarily bypassing a customer who must at some later point be sequenced onto the route, and thus may require backtracking to serve. All else is indeed equal because it was presumed the savings coefficients for the two pairs of customers were identical. Hence, we should array the savings coefficients in descending order by searching the matrix of savings coefficients such that when a choice exists we select the nearest neighbors first. For our hypothetical problem this results in the following array (again ignoring all $s_{ij} = 0$):

Customer i	Customer j	s_{ij}	Customer i	Customer j	s_{ij}
1	2	4	2	6	2
2	3	4	3	5	2
12	13	4	3	8	2
13	14	4	4	6	2
1	4	4	4	9	2
3	6	4	6	11	2
9	12	4	7	12	2
11	14	4	8	14	2
1	3	4	9	11	2
12	14	4	9	13	2
4	5	2	10	12	2
5	6	2	10	14	2
9	10	2	11	13	2
10	11	2	3	4	2
2	5	2	11	12	2
4	7	2	1	6	2
6	8	2	1	9	2
7	9	2	3	11	2
8	11	2	4	12	2
10	13	2	6	14	2
1	5	2	9	14	2
1	7	2	1	12	2
2	4	2	3	14	2

Now, applying the Clarke-Wright procedure we get the route: Warehouse-7-5-4-1-2-3-6-8-11-14-13-12-9-10-Warehouse, which covers a distance of sixteen units (a saving of two units of distance) and involves no unnecessary backtracking (see figure 2)—indeed it is the optimal route.



Note: Distance between any adjacent customers and between customers 5, 7, 8, and 10 and the warehouse equals one.

Figure 2. Nearest-neighbor solution to hypothetical routing problem

Conclusions

This paper has demonstrated that for routing problems for which the delivery network is laid out in a square grid, incorporating the nearest-neighbor concept into the Clarke-Wright heuristic is likely to be beneficial. In fact, so long as the grid is rectangular, it can be demonstrated easily that this conclu-

sion will hold. In both cases the reason for the conclusion is that there are likely to be a number of ties in the savings matrix and the order of selection of tied savings coefficients is crucial. Since at least a portion of many delivery networks will exhibit these characteristics, incorporation of the nearest-neighbor concept, as implemented here for the general case, is highly recommended. Accordingly we have incorporated this concept in our computer code. It should be emphasized, however, that for problems of large size this will increase the computer time substantially because of the additional search time involved.

[Received May 1978; revision accepted August 1978.]

References

Clarke, G., and J. W. Wright. "Scheduling Vehicles from a Central Depot to a Number of Delivery Points." *Operations Res.* 12(1964):568–81.

Garvin, W. W., H. B. Crandall, J. B. John, and R. A. Spellman. "Applications of Linear Programming in the Oil Industry." *Manage. Sci.* 3(1957):407–30.

Golden, Bruce L., Thomas L. Magnanti, and Hien Q. Nguyen. "Implementing Vehicle Routing Algorithms." *Networks*, forthcoming.

Hallberg, M. C., and W. R. Kriebel. *Designing Efficient Pickup and Delivery Route Systems by Computer.* Pennsylvania State University Agr. Exp. Sta. Bull. 782, 1972.

Schruben, L., and R. Clifton. "The Lockset Method of Sequential Programming Applied to Routing Delivery and Pickup Trucks." *Amer. J. Agr. Econ.* 50(1968): 854–65.

Turner, Wayne C., Prabhamar M. Ghare, and Leslie R. Fourds. "Transportation Routing Problem—A Survey." *AIIE Transactions* 6(1974):228–301.

Tyagi, M. "A Practical Method for the Truck Dispatching Problem." *Operations Res. Soc. Japan* 10(1968): 76–92.

A Framework for Economic Analysis of Livestock and Crop Byproducts Utilization

Wen-yuan Huang

Livestock manure and crop trash contain nutrients that can be processed as plant or animal food. Modern agriculturalists or practitioners often treat them as wastes and dispose of them into the surrounding environment, favoring the purchase of commercial fertilizers or feeds. However, in recent years a combination of changes has set the stage for reexamining such practices; namely, increased cost of commercial fertilizer and livestock feed, increased costs of waste disposal due to regulation, and improvements in waste management technology.

There were approximately 11,300 head of dairy cattle on Oahu in 1976, annually generating about 165,000 tons of raw manure. This manure contains considerable amounts of plant nutrients which could be used by the pineapple industry. Most of the manure is not utilized and, instead, is disposed of at considerable cost to the dairy industry. The waste also creates potential pollution problems in certain coastal areas of the island.

There are about 5,000 acres of pineapple land harvested annually on Oahu, generating about 250,000 tons of post-harvest plant material (trash). Most of the trash is harrowed down, field dried, and burned on the field, with the remains plowed into the soil as fertilizer. Considerable nutrients are lost and pollution is created because of trash burning.

With the cooperation of the Hawaii state government, considerable interest has been generated by dairy farmers and the pineapple industry in the use of byproducts to substitute for increasingly expensive imported feed and fertilizer. In 1976, a private cooperative was established to chop and remove the post-harvest pineapple plants and sell them to dairy farms as a roughage feed.

This paper presents an analytical framework for investigating the integrated use of agricultural byproducts. An example is used to illustrate the workings of this framework. The empirical results of an actual case study conducted in Hawaii are presented as a demonstration of the operational potential to the real world situation. Finally, the framework is extended into a generalized byproduct use model. The model accounts for both efficiency and distributional considerations.

Wen-yuan Huang is an assistant agricultural economist, Department of Agricultural and Resource Economics, University of Hawaii, and visiting assistant professor, Iowa State University.

This paper is published with the approval of the Director, Hawaii Agricultural Experiment Station at Oahu, as Journal Series No. 2292.

Conceptual Model

A simple analytical model is presented in this section. Figure 1 shows the flows of byproducts and payments between two farms (or enterprises) through a third-party enterprise—called the management firm—that specializes in processing waste. The total net benefit (TNB) of use of byproducts is defined as:

$$(1)\qquad TNB = \left(\sum_{i=1}^{2} f_i + \sum_{i=1}^{2} s_i\right) - \left(\sum_{i=1}^{2} P_i + \sum_{i=1}^{2} t_i + \sum_{i=1}^{2} l_i + \sum_{i=1}^{2} o_i\right) - r,$$

and the total net return (TNR_m) to the management firm is expressed as

$$(2)\qquad TNR_m = \sum_{i=1}^{2} (x_i - y_i - p_i) - r,$$

where f_i is value of the reprocessed inputs, feed (f_1), and fertilizer (f_2); s_i, the savings realized by avoiding conventional means for disposing of manure (dairy farm) s_1, and crop trash (crop farm) s_2; p_i, processing cost for transforming waste to production inputs (trash to feed, p_1, or manure to fertilizer, p_2); t_i, transportation cost of feed (t_1) and fertilizer (t_2); l_i, loss of fertilizer value because of crop trash (l_2) and manure removal (l_1); o_i, other costs; x_i, payment for reprocessed feed (x_1) or fertilizer (x_2); y_i, payment for crop trash (y_2) or manure (y_1); and finally, r is the minimum profit margin. The conditions for economic feasibility of byproducts use are $TNB > 0$ and $TNR_m \geq 0$.

Of these cost and return variables, feed value f_1 can be determined from the market value feed nutrients present in the trash. Its value is determined by prices paid for equivalent amounts of nutrients in commercial feeds. The value of the soil nutrients of the trash l_2 can be determined from prices for equivalent amounts of nutrients in commercial fertilizers. Similar procedures can be used for evaluating manure as usable fertilizer (f_2 and l_1).

The variable s_1 is saved cost that would otherwise be incurred by a dairy farm for treating biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and suspended solids of manure. Similarly, s_2 is the saved expense

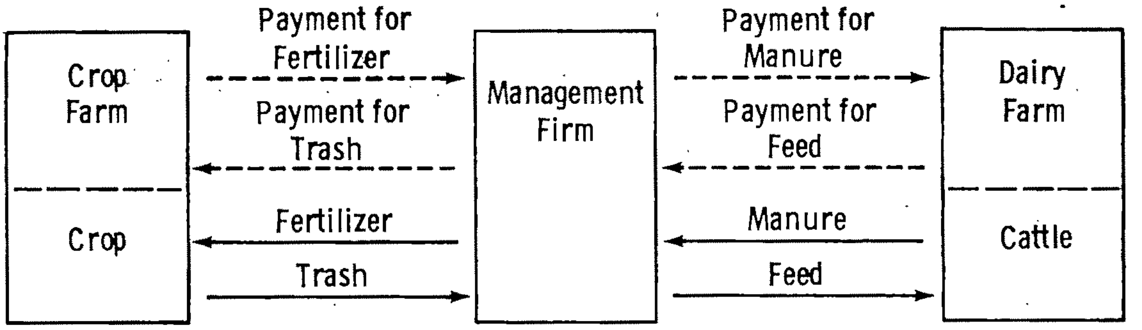


Figure 1.

incurred by a crop farm for avoiding pollution on the farm land from burning trash. In this instance, the value of s_2 is the sum of the imputed pollution prevention costs or payment to society for polluting the environment with pollutants: carbon monoxide (CO), hydrocarbons (HC), nitrogen oxide (NO_x), sulfur oxides (SO_x), and particulates.

In this system there are three feasible cases which may result for each party involved. In the first case, both farms gain from the activities of byproduct utilization; that is, $TNR_d > 0$, and $TNR_c > 0$, where

(3) $TNR_d = f_1 + s_1 + y_1 - x_1 - t_1 - l_1 - o_1,$

and

(4) $TNR_c = f_2 + s_2 + y_2 - x_2 - t_2 - l_2 - o_2.$

The cash flow $y_1 - x_1$ or $y_2 - x_2$ for buying and selling the byproducts in each farm may be positive or negative but is bounded below by the net benefit ($f_1 + s_1 - t_1 - l_1 - o_1$ or $f_2 + s_2 - t_2 - l_2 - o_2$) that each farm receives through byproduct utilization. In practice, the final outcome of the net cash flow in each farm probably will be determined through market exchange.

In the second case the dairy farm gains and the crop farm loses: $TNR_d > 0$; $TNR_c < 0$. In the third case, the crop farm gains while the dairy farm loses: $TNR_d < 0$; $TNR_c > 0$. The exchange of byproducts can occur only if the farm which gains makes a sufficient transfer payment to the other farm to cover its losses. The final net cash flow would likely be determined by the bargaining process.

Empirical Analysis

In this analysis, an investigation was conducted for the case of a firm purchasing pineapple green chop for processing into dairy roughage. Reciprocal processing of dairy manure was not investigated. Thus, the variables l_1, o_1, s_1, y_1, x_2, t_2o_2, f_2, and p_2, defined earlier, are set to equal zero. Equations (1), (2), (3), and (4) become

(5) $TNB = (f_1 + s_2) - (p_1 + t_1 + l_2) - r,$

(6) $TNR_m = x_1 - y_2 - p_1,$

(7) $TNR_d = f_1 - x_1 - t_1,$ and

(8) $TNR_c = s_2 + y_2 - l_2,$

with TNR_d, TNR_c, TNR_m, and TNB sequentially computed. Data used are from a report by Huang, Darval, Wayman, and Sanford.

Calculation of TNR$_d$

Several methods can be used to appraise the feed value of pineapple green chop (Gullison). Because the only accurate energy values available for pineapple green chop are total digestible nutrient (*TDN*) values, the amount of *TDN* contained in the pineapple green chop is used as the basis for evaluating its economic feed value. It should be pointed out, however, that the *TDN* criterion does have some inherent problems in that it tends to over-value roughages as compared to higher energy feedstuffs such as cereal grains. When net energy (*NE*) value of green chop is available, it should give a better estimation of nutrient value. The evaluation formula is given as

(9) $f_1 = w_1z_1 + w_2z_2,$

where w_1 is nonprotein total digestible nutrients (*NP-TDN*) in one ton of green chop; w_2, protein total digestible nutrients (*P-TDN*) in one ton of green chop; z_1, the price per ton of *NP-TDN* to be determined from commercial feed; and z_2 is the price per ton of *P-TDN* to be determined from commercial feed.

The values for z_1 and z_2 are derived from the nutrient contents and market prices of *NP-TDN* and *P-TDN*, respectively, in existing commercial feeds. The prices of two commercial feed mixes, alfalfa-cottonseed meal and alfalfa-corn meal are used to compute values of *NP-TDN* and *P-TDN* which also are used in estimating the commercial value of the byproduct feed, f_1. The economic imputed value of pineapple green chop is estimated at $24.00 per ton, as computed from alfalfa-cottonseed meal and $21.69 per ton for alfalfa-corn, assuming

Table 1. Estimated Economic Feed Values of Pineapple Green Chop

Feed Combinations	*NP-TDN* (in 1 ton of feed)		*P-TDN* (in 1 ton of feed)		Prices of Feed		*N-TDN* (in 1 ton of green chop)	*P-TDN* (in 1 ton of green chop)	Value of Green Chop[b]
	a_1[a]	a_2	b_1	b_2	c_1	c_2	w_1	w_2	f_1
	(ton)				($/ton)		(ton)		($/ton)
Alfalfa-cottonseed meal	.3987	.323	.127	.353	133.4	194.0	.086	.014	24.00
Alfalfa-corn meal	.3987	.735	.127	.075	133.4	162.6	.086	.014	21.69

[a] a_1 and b_1 refer to the amounts of *NP-TDN* and *P-TDN*, respectively, of the feed placed first in the first column (alfalfa); these values were obtained from nutrient requirement of dairy cattle, National Research Council No. 3, 1971. The price of that feed is c_1. Similar explanation holds for a_2, b_2, and c_2 (cottonseed or corn).

[b] Value of green chop per ton is computed using equation $f_1 = [w_1 w_2] \begin{bmatrix} z_1 \\ z_2 \end{bmatrix} = [w_1 w_2] \begin{bmatrix} a_1 b_1 \\ a_2 b_2 \end{bmatrix}^{-1} \begin{bmatrix} c_1 \\ c_2 \end{bmatrix}$

one pound of *TDN* in green chop is equivalent to one pound of *TDN* in the feeds substituted (table 1). The average economic feed value of the green chop becomes $22.88 per ton.

It was estimated that loss during delivery, storage, and feeding was 10%. The imputed feed value of field trash (f_1) then becomes $20.60 per ton. The dairy farmer pays $12.00 per ton ($x_1$) for the green chop and $4.00 per ton ($t_1$) for transporting the green chop from the pineapple field to his farm. Thus, the total net return to the dairy farm (from equation 7) is $4.60 per ton.

Calculation of TNR$_c$

Without use of byproducts for cattle feed and without enforcement of the Clean Air Act, the pineapple plants on the field at the end of a cycle are chopped down, field-dried, often burned, and then plowed into the soil. Some of the nutrients in the plant, therefore, remain in the field. With the process of byproduct utilization (Smith and Gillespie), the plants are harvested for cattle feed and thus these nutrients are removed from the field. Assuming one pound of nutrients (N, P_2O_5, K_2O, Ca, Mg, S, and Mn) in the plant is equal to one pound of nutrients from a commercial chemical fertilizer, about $51.10 worth of fertilizer per acre is needed to compensate for the nutrients removed from the field (table 2). This amounts to about $1.02 ($l_2$) per ton of green chop assuming that 50 tons of green chop are removed per acre.

There are two types of cost savings. When plants are removed from the field, fewer field operations are needed to prepare the land for the next planting. Cost saved from these field operations (chopping and burning) is estimated at about $20.00 per acre which amounts to $0.40 per ton of green chop removed.

With the removal of the trash from the field, the pineapple firm could avoid burning the trash and paying penalties for polluting the air, assuming the burning would otherwise be the least-cost method to dispose of the trash. It should be pointed out that

Table 2. Estimated Value of Usable Plant Nutrients per Acre Remaining in the Soil after 50 Tons per Acre of Post Harvest Plants Are Chopped, Burned, and Incorporated into the Soil

Nutrient Type	Amount of Nutrients in the Plants[a]	Amount of Nutrients in the Trash	Usable Nutrients n_1	Commercial Type	Fertilizer Price m_i[e]	Market Value $n_i \times m_i$
	(ton)				($/ton)	($)
N	0.1860	0.0558[b]	0.0279[d]	Urea	203.06	5.66
P_2O_5	0.0400	0.0400	0.0400	Superphosphate	184.00	7.36
K_2O	0.1790	0.1790	0.1790	KCl	151.00	27.03
Ca	0.1250	0.1250	0.1250	$CaCO_3$	53.00	6.63
$Mg + S$	0.0770	0.0231[c]	0.0231	$MgSO_4$	164.00	3.79
Mn	0.0025	0.0025	0.0025	$MgSO_4$	258.00	0.63
Total						51.10

[a] Figures were derived from reports by Wayman and Sanford.
[b] Assume 70% of nitrogen is lost through burning.
[c] Assume 70% of sulphate is lost through burning.
[d] Assume half of the remaining N is used by the next crop.
[e] Prices in Oct. 1976.

removal of the trash could lead to increased soil loss. Imputed cost of soil loss is not considered here. The savings were estimated to be \$1.94 per ton. By adding the cost saved from fewer field operations to the cost saved from paying penalties for burning the trash, the pineapple firm saved \$2.38 (s_2) per ton of green chop removed. If air pollution cost is not considered, the value for s_2 is \$0.40 (table 3).

The management (intermediary) firm pays \$120.00 per acre to the pineapple farm for the privilege of harvesting the plants. This amount is equivalent to \$2.40 (y_2) for each ton of green chop removed from the field. The net return to the pineapple farm from equation (8) is

$$TNR_c = s_2 + y_2 - l_2 = 2.38 + 2.40 - 1.02 = \$3.76 \text{ per ton.}$$

Calculation of TNR$_m$

The cost of transforming (harvesting and handling) the plant trash into dairy feed includes farm machinery, vehicles, and service equipment, operator wages, field manager salary, other machinery, insurance, and miscellaneous costs. Total costs of these items, including sales tax, was calculated at \$4.90 (p_1) per ton of green chop produced (Huang et al.). Payment to the pineapple farm for harvesting one ton of green chop as calculated earlier is \$120/50 = \$2.40 ($=y_2$). On the other hand, the firm receives \$12.00 per ton (x_1) from selling the green chop to the dairy farm. The total net return excluding profit margin is [with $r = 0$ from equation (6)]

$$TNR_m = x_1 - (y_2 + p_1) = 12 - (2.40 + 4.90) = \$4.70 \text{ per ton.}$$

Calculation of TNB

By using equation (5), the total net benefit of using pineapple green chop as cattle feed, excluding a profit margin, is

$$TNB = (f_1 + s_2) - (p_1 + t_1 + l_1) = 20.60 + 2.38 - (4.90 + 4.00 + 1.02) = \$13.06/\text{ton.}$$

This computation result implies that using each ton of the green chop as cattle feed instead of leaving the post harvest pineapple plants on the field as fertilizer results in \$13.06 per ton of net benefit generated in the process. This amount is large enough to pay an adequate profit margin to the management firm. The conditions of economic feasibility are satisfied.

Byproduct utilization in this case study is limited to the use of pineapple plants as cattle feed. The apparent effects are a significant reduction in the amount of imported feed and an increase in the amount of imported inorganic fertilizers. In terms of dollar values for Hawaii, green chop used as feed reduces expenses related to the importation of feeds by \$19.58 per ton ($f_1 - l_1$). Further studies to evaluate possible indirect benefits and costs to the state economy are needed.

Extensions and Implications

By extending the analysis, a generalized optimization model can be built to illustrate the interrelationships between byproduct utilization and cost of commercial fertilizer, feeds, pollution, transportation, and byproduct processing. Use of the model could check the feasibility condition and search for the optimal utilization of byproducts among many farms. For the general model, it is assumed that there is a total of N farms in the crop and livestock industries. Each farm can either keep its byproduct or sell it to either a crop farm or a livestock farm through a management firm.

The objective of the byproduct utilization model, defined below (10–16), is to find the amount of byproducts used among these N farms. The model is a typical linear programming model:

Maximize

Table 3. Estimated Air Pollution Costs in Burning Pineapple Trash in Hawaii

Air Pollutant	Ton/Acre[a] (1)	Cost/Ton[b] (2)	Cost/Acre (1) × (2) = (3)	Cost/Ton[c] (3) ÷ 13.9
		($)		
Sulfur oxides	negl.	464.00	0	0
Particulates	0.093	220.00	20.45	1.47
Carbon monoxide	0.136	7.37	1.00	0.07
Hydrocarbons	0.0487	114.00	5.55	0.40
Nitrogen oxides	not avail.	—	—	—
Total				1.94

[a] Data were obtained from an experiment conducted by Dollar.

[b] The pollution cost from one ton of pollutant was derived from a paper by Small. The data in his paper were used mainly for vehicle pollution. The data consist of the cost of human health and damage to building (such as house) exteriors. To use the data in this paper, it was assumed that pollution costs in burning pineapple trash were the same as burning fuel by vehicles. This assumption would be valid only if pineapple trash was burned near populated residential areas, which is the situation in this case study.

[c] It was estimated that one acre of pineapple plants has 13.9 tons of trash in dry matter basis.

$$(10) \quad Z = \sum_{n=1}^{N} \sum_{m=1}^{N} [(F_{nm} + S_{nm}) - P_{nm} + T_{nm} + L_{nm} + O_{nm})]Q_{nm},$$

subject to

$$(11) \quad Z + \sum_{n=1}^{N} \sum_{m=1}^{N} R_{nm}Q_{nm} \geq 0,$$

$$(12) \quad F_{nm} = (\mathbf{W})(\mathbf{A})^{-1}(\mathbf{C}),$$

$$(13) \quad L_{nm} = \sum_{k=1}^{K} N_{nmk}M_k,$$

$$(14) \quad S_{nm} = D_{nm} + \sum_{i=1}^{I} E_{n_i}G_i,$$

$$(15) \quad \sum_{n=1}^{N} Q_{nm} \leq U_m^s, \text{ and}$$

$$(16) \quad \sum_{m=1}^{N} Q_{nm} \leq U_n^c,$$

where $n = 1, 2, \ldots, N$ and $m = 1, 2, \ldots, N$, and Z are total net benefits generated from byproduct utilization in a defined system;

R_{nm}: minimum profit margin in transforming unit byproducts of farm n into inputs for farm m;

F_{nm}: feed value or plant nutrient value per ton to farm n by using farm m's byproducts;

S_{nm}: saving from reducing costs of disposal operation and pollution to farm n in selling each ton of its byproducts to farm m through a management firm;

D_{nm}: reducing cost of disposal operation to farm n in selling each ton of its byproducts to farm m through management firm;

E_{ni}: quantity of pollutant i in each ton of byproduct from farm n;

G_i: pollution cost per ton of pollutant i;

P_{nm}: processing cost per ton to a management firm transforming byproducts of farm m into inputs for farm n;

T_{nm}: transportation costs for one ton of byproduct from farm m to farm n;

L_{nm}: value of lost plant nutrients to farm n for each ton of byproduct removed and sold to farm m through the management firm;

O_{nm}: other costs per ton incurred by using farm n's byproduct as an input to farm m;

Q_{nm}: amount of byproduct transfer from farm m to farm n through the management firm;

$\mathbf{W}$: a row vector $(\mathbf{W}_{nm})$ where $\mathbf{W}_{nm}$ is the plant or feed nutrient k contained in the byproduct of farm m and used in farm n;

$\mathbf{A}$: a matrix (a_k) where a_k is the amount of plant or feed nutrient k in one ton of commercial fertilizer or feed;

$\mathbf{C}$: a column vector (c_l) or (c'_l) where c_l or c'_l is the market price of commercial feed or fertilizer, respectively;

N_{nmk}: usable plant nutrient k in each ton of byproduct of farm m if the byproduct is not sold to farm n through the management firm;

M_k: market price of plant nutrient k;

U_m^s: upper limit of byproduct supply from farm m; and

U_n^c: maximum consumption of all the products by farm n.

The final solution of the model will yield values for Q_{nm} which are the amounts of byproducts transferred from farms m to n through the management firm. The question remaining is to determine the payment from each farm to the management firm for the usable inputs and the payment from the firm to the farms for their byproducts.

Equation (17) set a baseline value for this determination:

$$(17) \quad \sum_{m=1}^{N} (f_{nm} + S_{nm} + Y_{nm} - X_{nm} - T_{nm} - L_{nm} - O_{nm}) \geq 0,$$

where $n = 1, 2, \ldots, N$; X_{nm} is the payment to the management firm from farm n for the byproduct of farm m; and Y_{nm} is the payment to farm n from the firm for its byproduct which later is used by farm m. The minimum value of the net cash flow for farm n is given by

$$(18) \quad \sum_{n=1}^{N} (X_{nm} - Y_{nm}) = \sum_{m=1}^{N} (F_{nm} + S_{nm} - F_{nm} - L_{nm} - O_{nm}),$$

for $n = 1, 2, \ldots, N$. The final net cash flow for farm n, as mentioned earlier, is probably determined by a negotiation process.

The values of the net cash flows and the values of Q_{nm} can be used to calculate the total net return to the management firm ($TNRM$) by

$$TNRM = \sum_{n=1}^{N} \sum_{m=1}^{N} (X_{nm} - Y_{nm} - P_{nm})Q_{nm}.$$

Integrated byproduct utilization is economically feasible for the management firm if $TNRM$ is greater than or equal to the minimal required profit margin $R \left(\sum_{n=1}^{N} \sum_{m=1}^{N} R_{nm}Q_{nm}\right)$. Excess profit ($TNRM - R$), if any, perhaps could be redistributed to farms.

The suggested model could be used continually to monitor the optimal use of byproducts. Because of changes in fertilizer prices (c'_l), feed prices (c_l), processing costs (P_{nm}), transportation costs (T_{nm}), or environmental quality regulations (G_i), the value to the industry of certain byproducts may vary. The prevailing product utilization practices may then need to be changed in order to achieve the optimal use of the byproduct. This is the case in using pineapple green chop as cattle feed in Hawaii. Re-

cent increases in the prices of imported alfalfa and other feeds have made the green chop, which previously was not economical, become an economical feed as indicated in this paper. This situation could occur for other types of byproducts as well. Therefore, the model is valuable for use in evaluating utilization, in searching for optimal use, and in planning future use of the byproducts under different economic settings.

[Received May 1977; revision accepted July 1978.]

References

Dollar, Alexander M. Personal communication, 19 Sep. 1977, Department of Public Health, University of Hawaii.

Gullison, A. E. *Feeds and Feeding*. Reston, Va.: Reston Publishing Co., 1975.

Huang, W. Y., P. Darval, O. Wayman, and W. G. Sanford. "Economics of Post Harvest Pineapple Plant as Cattle Feed: A Case Study." Dep. Agr. and Res. Econ., report prepared for the members of Pineapple Byproducts Utilization Committee, University of Hawaii, 1976.

National Research Council. *Nutrient Requirement of Dairy Cattle*, no. 3. National Academy of Science, Washington, D.C., 1971.

Sanford, W. G. "The Effects of Trash Removal on the Growth Yield and Fertilizer Requirements of Pineapple." Proceedings of the 9th Hawaii Fertilizer Conference, Coop. Extens. Serv., University of Hawaii, Misc. Pub. 133, 26 Apr. 1976.

Small, Kenneth A. "Air Pollution Costs of Transport Modes." *J. Transport Econ. and Policy*, May 1977.

Smith, M. Ray, and Bruce A. Gillespie. "Harvesting Pineapple Plants for Livestock Feed in Pacific Region." Amer. Soc. Agr. Eng. Pap. PC-76-18, 1976.

Wayman, Oliver. "Progress Report on the Use of Post Harvest Pineapple Plants as Cattle Feed." Report prepared for members of the Hawaii House Committee on Agriculture, 24 Feb. 1976.

Pesticides, Information, and Pest Management under Uncertainty

Gershon Feder

World use of chemical pesticides has been expanding in the last two decades at an unprecedented rate, even though many of them have a negative effect on human health, wildlife, and economic activities. Langham and Edwards were among the first to attempt to measure the extent of such externalities. More refined models have been developed by Hueth and Regev, Taylor and Headley, and Feder and Regev. Because of the externalities inherent in pesticides, it would seem that their use is excessive.

This situation explains the increased efforts to develop technologies which substitute, in part, for pesticides while still reducing infestation levels and pest damage (Hall 1977a, b). An important and related line of action is the dissemination of information regarding old and new technologies. Imperfect information adds perceived uncertainty to the "real" uncertainty regarding various components of the ecosystem. Uncertainty has been hypothesized as a major factor in inducing pesticide use (Norgaard, p. 49). It is thus a matter of importance to investigate the impact of uncertainty on decisions made by risk-averse farmers regarding pesticide use and the way it affects reaction to various changes.

The purpose of this paper is to present such an analysis by introducing random elements in several components of the pest-pesticide-crop system. While adopting several simple features of earlier works on this topic, the model relies on two general hypotheses regarding individual behavior under risk: maximization of expected utility and risk aversion. Within the framework of such a model it is possible to evaluate the impact of improved information regarding old and new technologies as well as the relations between information acquisition, the cost of information, and the effects on pesticide use. In particular, the rationale for a market in pest management information is established.

The first section of this paper presents the pest-pesticide-crop model and farmer behavior. The next two sections analyze model implications given uncertainty regarding the rate of damage and rate of infestation. The following two sections deal with the effects of two alternative forms of uncertainty with respect to the effectiveness of pesticides.

The Pest-Pesticide-Crop Model

The formulation of the model follows the design of the "decentralized" decision model of Feder and Regev (pp. 79–82). The latter, in turn, relies on earlier works such as Shoemaker (1973 a, b), Talpaz and Borosh, and Hall and Norgaard. In essence, these models are highly simplified descriptions of a complicated system. In the present case, the simplifications are necessary for an analysis of the role of risk in farmers' pest management decisions.

The model focuses on a single farmer within a region containing many similar units. At any given period (the definition of a period is discussed below), there are a number of pests (say N) present on the farm.[1] Pests cause damage to the crop (or livestock) in an amount related to their number, say $D(N)$ dollars. It is convenient to specify the damage function as

$$D(N) = \delta \cdot N, \tag{1}$$

where δ is the damage caused by a single pest (assumed to be independent of the total number of pests).

In general, both δ and N are viewed by the farmer as random variables (with respective means $\bar{\delta}$ and $\bar{N}$), since the number of pests is not known, while the damage per pest is affected by temperature, humidity, differences in plant susceptibility at different periods, arrival of new pest biotypes, and other factors which are not known with certainty.

The farmer can affect N (or its distribution) within the time period considered by applying pesticides (the volume of which is denoted by x), thus eliminating a proportion k of the pest population. In some instances there are other pest-reducing actions which can be adopted, such as fences, screens, and plastic covers. However, these alternative control methods tend to be of a fixed nature, in the sense that once the control has been applied,

Gershon Feder is an economist at the Development Research Center, World Bank.

Views expressed are those of the author and do not necessarily reflect those of the World Bank. The paper benefitted from useful comments by A. P. Gutierrez, P. L. Scandizzo, and three anonymous referees.

[1] As in previous models, only a single crop and a single species of pest is considered. For simplicity, no differences between age groups are assumed. The analysis of a multicrop-multispecies case is considerably more complicated, and will not change the essence of the results.

it is effective for the whole season. The costs of such inputs will be included in a fixed cost element, say C_o, which will be introduced in the profit function. The population of pests in the model implies those pests which are present in spite of the alternative (nonchemical) controls.

The impact of pesticides on pests is reflected through a "kill function" (or dosage response function) which relates the proportion of pest population killed (k) to the amount of pesticides applied, assuming decreasing returns to scale.

(2) $k = k(x);\ k' > 0;\ k'' < 0;\ k(o) = 0;\ k(\infty) = 1.$

The kill function also may include a random element because pesticide effectiveness depends on such factors as weather, temperature, and wind.

The subject of the farmers' planning horizon and the length of the period considered in the model deserves special attention. As argued in Feder and Regev (p. 79), mobile pests can reinfest the farm several times within one crop season regardless of the amount of pesticides applied by the individual farmer. This is so, because with such pests it is the total degree of infestation in the region (on which the single farmer has only negligible control) that essentially determines the number of pests present on the farm once the effect of previous spraying dissipates. Under such circumstances, the farmer has no incentive for considering more than one period at a time, although there will be several periods in a crop season and possibly several applications of pesticides. Such a static decision framework is adopted in the present model. In the case of immobile pests (where a dynamic decision framework may be warranted), the static framework of the present model should be viewed as a simplification necessitated by the complications of analyzing a stochastic dynamic system, and the results should be qualified accordingly.

Aside from pesticides there are additional inputs which are related to pest management, although not all directly affect the number of pests present. Such inputs include the adoption of specific planting patterns, pest resistant varieties of plants, timing, and quantity of water and fertilizer applications. The adoption of such techniques can be viewed as a factor reducing the mean of the distribution of the damage level ($\bar{\delta}$), while the cost is of a fixed nature and is not related to the amount of information (e.g., consultants charge a per acre rate). All other agricultural inputs are assumed to be applied in an optimal manner, and thus the only control variable in the system at this stage is the amount of pesticides to be applied, if pesticides are to be applied at all.

The contribution to operational profits during the period considered, say Π, can be expressed as follows:

(3) $\Pi = (\Pi_o - C_o) - \delta N[1 - k(x)] - cx,$

where $(\Pi_o - C_o)$ denotes profits that would have been realized if no pest were present (i.e., $N = 0$); $N(1 - k)$ is the number of pests surviving after pesticide application; and cx is the total cost of pesticide application (c denoting the cost per unit). The distribution of damage levels may change in different periods as the plant develops, but is taken as given for any time period.

Assuming risk aversion on the part of farmers (Norgaard, Hall 1977b), a concave utility function $U(\Pi)$ is hypothesized, such that

(4) $U = U(\Pi);\ U' > 0;\ U'' < 0.$

The farmer's objective is the maximization of expected utility by choosing the appropriate level of pesticides, i.e.,

(5) $\max_x EU\{(\Pi_o - C_o) - \delta N[1 - k(x)] - cx\},$

where E is the expectations operator.

First order conditions for optimum are given by

(6a) $\dfrac{\partial E(U)}{\partial x} = E\{U'(\delta N k' - c)\} \leq 0$ (6a), and

(6b) $x\dfrac{\partial E(U)}{\partial x} = 0,$

and the second order condition is satisfied because

(7) $$\frac{\partial^2 E(U)}{\partial x^2} = E\{U''(\delta N k' - c)^2\} + E\{U'(\delta N k'')\} < 0.$$

The sign of (7) is verified by the assumptions $U'' < 0$, $k'' < 0$. The optimal amount of pesticides implied by (6a) and (6b) is "private," not social because the farmer ignores the damage inflicted on wildlife and humans by pesticide drifts and residues and because of the other externalities related to pesticides used.

The model presented above belongs to a general class involving decision making under uncertainty, the mathematical properties of which are analyzed in Feder (1977). Due to space considerations, the mathematical derivations of results will not be developed in the present paper. Rather, all the assertions in the following sections are rigorously verified in Feder (1978), and are available to interested readers upon request to the author.

An additional assumption is adopted at this stage regarding the attitudes towards risk: The Arrow-Pratt measure of absolute risk aversion (given by $-U''/U'$) is assumed to be nonincreasing. That is, as income increases, aversion to risk is assumed to decline or remain constant, but not to increase. This is a plausible pattern of behavior, as argued by Arrow.

Implications of the Pest-Pesticide Model: Uncertainty in the Rate of Damage

It will be convenient to conduct the analysis by considering one random element at a time. We thus

start by assuming that the rate of damage per pest (δ) is random, while all other variables and parameters (including N) are nonrandom. It is noted that in this framework riskiness increases with N and decreases with x, i.e., pesticides reduce risk.

One result which is intuitively expected can be derived from equations (6a, 6b); that is, the level of pesticides application (x) increases with higher infestation levels (N). With higher pest numbers, the marginal benefit of pesticides increases while the marginal cost c is constant, thus inducing higher volume of pesticide use.

Because the relation between x and N is monotonic, and because at $N = 0$ obviously $x = 0$, there must exist some level of N, say N^*, at which the farmer is indifferent between applying pesticides and not applying pesticides at all. At pest levels below N^* pesticides are not applied. The critical pest level N^* (defined by $E\{U'[\delta N^* k'(o) - c]\} = 0$) is referred to as the "economic threshold population" and has been discussed extensively in the literature on pest management. We note that the economic threshold population is defined for a given distribution of δ, for a given cost of pesticides application, and for a given fixed cost C_o.

It can be shown that a reduction in the average rate of damage ($\bar{\delta}$) and an increase in the cost per unit of pesticide (c) will increase the level of the economic threshold (N^*) because such changes induce lower levels of pesticide use when N is low. As for the fixed cost (C_o), it has no effect on N^* when absolute risk aversion is constant (because in that case the relation between pesticide use and infestation level is unchanged). However, with decreasing absolute risk aversion (which implies more risk aversion at low levels of profit), an increase in the fixed cost will reduce expected levels of profit and thus induce higher pesticide use for any given level of infestation, so as to reduce risk. Because this is true for all N, it follows that the level of N at which there is indifference between no pesticides and one unit of pesticides (N^*) is lower with higher fixed costs. Lower threshold levels imply more frequent use of pesticides because pesticides will be applied at infestation levels which would not initiate response otherwise and thus are not desirable from a social welfare point of view.

It should be noted that while the impact of an increase in pesticide costs on pesticide dosage may be ambiguous at high levels of infestation, it has an unambiguous negative effect on the frequency of application (through the increased economic threshold). At high levels of N, risk and risk aversion are high if absolute risk aversion is decreasing. In that case, an increase in pesticide cost (c) increases further risk aversion and the incentive to reduce pesticide use may be checked by a tendency to increase use so as to reduce risk at the margin. With constant absolute risk aversion, this ambiguity does not appear.

An increase in the mean of δ will induce a higher level of pesticide application. This is intuitively expected because, as the expected damage per pest increases, there is an incentive to further reduce the number of pests on the farm by applying more pesticides. This result, together with the impact of changes in $\bar{\delta}$ on frequency of use, underscores the importance of policies for dissemination of technologies such as resistant plant varieties and other cultivation methods which reduce pest damage.

Because a reduction in $\bar{\delta}$ increases expected utility, farmers will agree to pay some fixed cost (as long as their expected utility is not reduced) for the acquisition of information and technology leading to a given reduction in $\bar{\delta}$. In fact, under such circumstances one would expect a commercial market to emerge where agents sell information leading to reduction in $\bar{\delta}$ and also information leading to reduced uncertainty. Indeed, such a market is already functioning and growing fast where the agents are consultants not related to pesticide producers (Hall 1977a, b). These consultants charge a fixed rate per acre for their services. Such a cost is accommodated in the present model as a component in the fixed cost C_o, because it is not related to the level of pesticide use.

The result of acquiring information of this type is to reduce pesticide use and frequency of applications, even though the information is costly. This prediction is confirmed by the results in Hall (1977a), who concludes on the basis of a survey among cotton and citrus growers in California that pesticide use dropped 33%–66% for farmers using pest management consultants.

The Impact of Risk

It has been argued (Norgaard, p. 99) that a major motivation for pesticide applications is the provision of some "insurance" against damage; that is, the existence of uncertainty in the pest-pesticide system is by itself a factor leading to a higher and a more frequent use of chemicals. These intuitive impressions are verified by the present model. It can be shown that an increase in the degree of uncertainty regarding the damage per pest will cause an increase in the volume of pesticide application for any given level of N and c, even though the mean value of δ remains unchanged. By increasing x, the farmers reduce the level of risk at the margin (which was increased due to the change in the distribution of δ). This result is contrary to the standard result for the firm under production uncertainty, where an increase in uncertainty will cause a decline in production and a decrease in input use (Batra, p. 58). The explanation for this result is that in the present case the input (pesticides) reduces risk, while in standard models of the firm the inputs increase the risk.

The discussion is demonstrated in figure 1. Panel (a) describes two alternative distributions of the

damage per pest. Both distributions have an identical mean ($\bar{\delta}$), but distribution d_2 is more dispersed and implies a higher degree of risk relative to distribution d_1 (Feder 1977, Rothschild and Stiglitz). Panel (*b*) presents the relationships between optimal pesticide level and the degree of infestation corresponding to the two densities. The response function $x(d_2)$ that corresponds to the more risky density function d_2 lies to the left of $x(d_1)$, implying higher pesticide applications for any infestation level above the economic threshold population N^*_2. In particular, the economic threshold population corresponding to d_2 is lower than the threshold level under d_1 ($N^*_2 < N^*_1$). This verifies that with a higher level of uncertainty there will be a more frequent use of pesticides. Obviously, a response function corresponding to a situation of full certainty will lie to the right of $x(d_1)$.

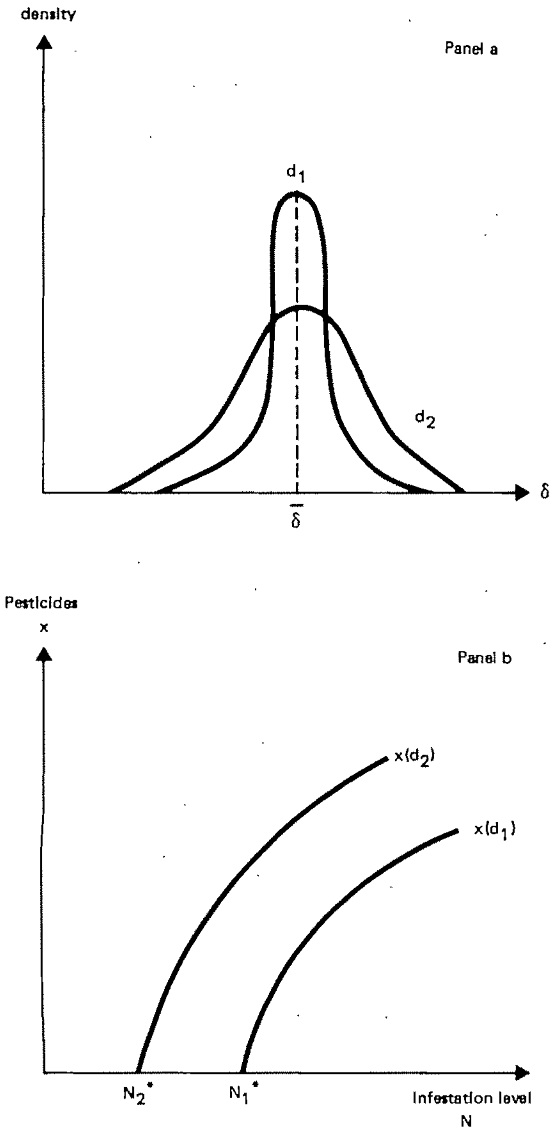


Figure 1. The impact of uncertainty

While part of the uncertainty regarding δ is real (i.e., it is a result of genuine random factors), there is a portion which is perceived in the sense that it exists in the farmer's mind because of insufficient access to available information. Some of the variability of δ can be reduced by the same technologies that reduce the mean of δ. However, even technologies that do not change the average rate of damage are beneficial for the farmer if they can reduce the degree of uncertainty. The provision of information having such an effect is obviously a matter of importance for social welfare because it will reduce pesticide use which currently may be excessive due to the disparity between private and social costs.

Furthermore, as reductions in the degree of uncertainty increase farmer's expected utility, farmers can be charged a fixed cost for such information. This would also explain the emergence of commercial markets for information leading to reduction in the degree of uncertainty (as well as the reduction in $\bar{\delta}$). That such information is indeed being sold is evident from the findings in Hall (1977a, b), who reports a significant reduction in yield and profit variability for farmers using consultants. For a given reduction in the uncertainty, a farmer will pay a fixed cost, the upper limit of which is the level that retains his expected utility unchanged (relative to a situation with the original degree of uncertainty).

Uncertainty Regarding the Degree of Infestation (N)

So far the analysis assumed that N was nonrandom. It is technically easy to replicate the preceding analysis assuming that N is random while δ is fixed, because mathematically δ and N perform the same role in the objective function. In this section, because N is random, the concept of economic threshold population (N^*) needs to be replaced by the economic threshold mean population (to be denoted by $\bar{N}^*$). The latter concept refers to a distribution with a mean at such a level that leaves the farmer indifferent between applying some pesticides or not applying any (for a given level of δ and costs per unit).

The uncertainty regarding N is due essentially to the inability of farmers to count the number of pests present at the beginning of the period. Through sampling, farmers generate a subjective distribution of N, but the distribution is probably affected by prior beliefs and experiences. More efficient estimation techniques will reduce the degree of risk (without changing the mean). This will reduce the volume and frequency of pesticide use. Cultivation techniques that support a higher population of natural enemies of the pest and allow them to operate more efficiently will reduce the mean of N ($\bar{N}$).

Similarly, the use of screens and special cultivation techniques may reduce pest accessibility to the crops (or livestock), which implies a reduction in $\bar{N}$ and thus a reduction in pesticide use.

Such changes increase farmers' expected utility; and, as indicated in the earlier discussion, they may be beneficial for society as a whole. For the same reasons as in the case of random δ, a commercial market for information leading to these changes in the distribution of N is functioning (obviously the same economic agents engage in selling such information). As in the earlier analysis, the net result of information acquisition is a reduction in the frequency and quantity of pesticide use, even though a fixed charge per acre is paid for such information.

Uncertainty Regarding the Effectiveness of Pesticides

The preceding analysis assumes that the farmer has perfect knowledge of the relation between pesticide and pest mortality (i.e., the kill function $k(x)$ was treated as nonrandom). However, real and perceived uncertainty may in fact prevail with respect to this element of the system. For instance, the number of pests exposed at a particular point in time is random. Changing wind, humidity, and temperature conditions may influence the effectiveness of pesticides. Lack of information adds a subjective element of uncertainty, and thus it will be proper to investigate the impact of randomness in the kill function, assuming δ and N to be nonrandom for simplicity.

A major problem in the analysis of this subject arises because there is no obvious way of specifying the element of risk in $k(x)$. In general, two possible situations may prevail: (*a*) the variation in pest response to the pesticide declines for higher dosages of pesticide; and (*b*) the variation increases with higher dosages. These two situations are demonstrated in figure 2, under panels a and b, respectively. In reality there are probably pesticides of both types. The first type is characterized by long durability of effect and is highly toxic, while the second is of short residue and/or of low toxicity. Parathion and DDT are examples of type *a*, while Malathion and Pyrethrods belong to the second group (Gutierrez).

A specification that reflects situation (*a*) implies that the degree of variability declines as the average rate of pest survival declines. One possible way of approximating such a relation is

$$1 - k(x) = \epsilon[1 - h(x)], \tag{8}$$

where ϵ is random with mean $\bar{\epsilon}$ and $h(x)$ has properties similar to those of $k(x)$, as specified in equation (2). The term $[1 - k(x)]$ is the actual (random) survival rate of pests for any given x. The term $[1 - h(x)]$ may be viewed as the theoretical survival rate under ideal (laboratory) conditions. The random factor ϵ reflects various environmental and biological factors as well as subjective uncertainty.

Adopting specification (8), the model remains technically the same as in the previous sections except that ϵ replaces δ or N as the random variable. The results of the earlier analysis then apply directly: the volume of pesticide application in a given period increases with the degree of uncertainty regarding pesticide effectiveness because there is an incentive to move into the range of higher x values where the degree of variability of pesticide impact is reduced. This implies also that the threshold level of N is reduced with higher ϵ variability, yielding a more frequent use of pesticides. A reduction in $\bar{\epsilon}$ which reflects a more potent pesticide, will reduce pesticide use.[2] This latter result reflects the fact that with a more effective pesticide, a smaller quantity is needed to maintain a given level of average kill. Intuition may be somewhat misleading in this case since it would seem that with higher effectiveness and unchanged price more will be demanded of the pesticide.

The increased effectiveness of the pesticide may be achieved either by obtaining information as to the proper way of its application, or by buying an improved variety of the chemical. In the first case, an analysis analogous to that of previous sections demonstrates that the farmers will agree to pay the fixed cost (C_o) required to obtain and apply the new knowledge, and that whatever the fixed cost is the use of pesticide will decline. In the case of improved material, farmers are willing to pay a higher variable cost (c) for the better chemical as long as their expected utility is not reduced. It can be shown, however, that even if they pay the maximal price for improved chemicals (i.e., a price such that their expected utility remains unchanged), the overall amount of pesticides used will be lower. It is thus to the benefit of society to promote the development of pesticides and methods of application that perform more effectively under field conditions (even though they are not more effective in the laboratory) provided they do not cause higher environmental damage. Reduction of the uncertainty in pesticide effectiveness is another worthy social goal.

While pest management consultants' work probably involves such effects, it is not obvious to what extent a chemicals salesman will provide information to this end. Reduction of $\bar{\epsilon}$ through the sale of more potent pesticides may be consistent with the agent's aims, because a higher price for the better material is possible, and the agent's revenue may still increase. However, since it is not common for salesmen to charge for advice, it is not likely that they will provide information reducing the variabil-

[2] The pesticide is more potent in the sense that under field conditions it is more effective than before (e.g., because it is less sensitive to humidity levels). The performance under ideal laboratory conditions (reflected by $h[x]$), is not changed when $\bar{\epsilon}$ is changed.

ity in ϵ. Neither will they be enthusiastic about reducing the means of δ, N, or their degree of variation.

The preceding analysis assumed a specification consistent with situation (*a*) of figure 2. An approximation for situation (*b*) is given by

$$k(x) = \epsilon h(x), \tag{9}$$

where $h(x)$, as before, is the kill rate under ideal conditions, and ϵ is random with mean $\bar{\epsilon}$. It can be shown that specification (9) implies higher variability of the kill rate with higher levels of x, consistent with panel (*b*) of figure 2. With specification (9) some of the results of the model are contrary to those of the earlier analysis. For instance, an increase in uncertainty regarding pesticide effectiveness (while $\bar{\epsilon}$ remains constant) will cause a decline in the amount of pesticide applied and will reduce the frequency of applications by increasing the threshold level of N. The difference in impact (relative to the earlier analysis) is a result of the fact that under specification (9) pesticides are not a risk-reducing input, but rather with higher x levels the distribution of utility becomes more dispersed. An increase in uncertainty regarding ϵ induces the farmer to retreat into lower levels of x, such that risk is reduced.

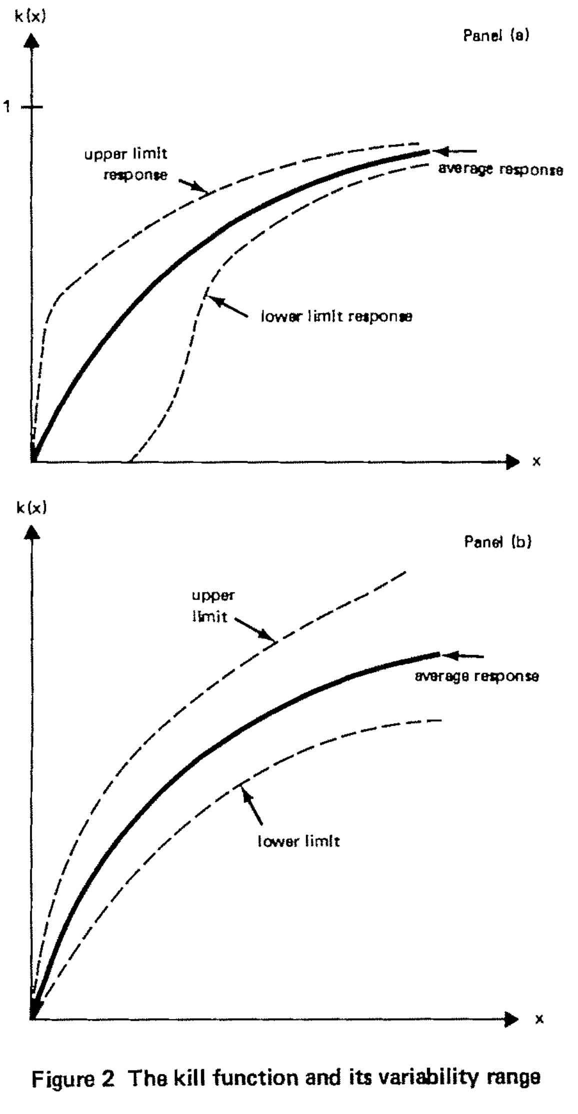


Figure 2 The kill function and its variability range

It is this variety of pesticides for which chemical salesmen have an incentive to provide farmers with information leading to reduced perceived uncertainty regarding effectiveness of the pesticide. Similarly, because with this type of pesticide an increase in the mean of ϵ ($\bar{\epsilon}$) will induce a higher and more frequent pesticide use, salesmen have an incentive to promote pesticide varieties and application technologies that increase pesticide effectiveness in the field, while such was not the case with the alternative specification of $k(x)$, unless an appropriately higher cost could be charged for more potent pesticides.

Because farmer's expected utility is increased by reduced uncertainty and higher $\bar{\epsilon}$, a higher fixed or variable cost related to these changes will be acceptable (up to the point where expected utility remains the same as in the initial situation). Consultants therefore will be inducing higher pesticide use when providing information on this type of chemical. However, as evidence suggests that with consultants the use of pesticides decreases, it must be concluded that in most cases the effect of pesticide-substituting information provided by consultants (regarding δ and N) outweighs the effect of information regarding pesticides of specification (9).

Results regarding changes in fixed costs in the present version of the model are contrary to those of the eariler sections, while for a change in variable costs (c) it is possible to conclude $\frac{dx}{dc} < 0$ whether or not absolute risk aversion is constant. However, only under constant absolute risk aversion one can show that pesticide use increases with higher δ and N levels, while with decreasing absolute risk aversion the sign is inconclusive. This follows from the fact that with higher levels of δ and N, the marginal benefit of spraying increases, but, on the other hand, such circumstances induce higher risk aversion and therefore reluctance to increase x (thereby increasing risk). The economic threshold level of N can be shown to be negatively related to the level of δ.

[*Received October 1976; revision accepted July 1978.*]

References

Arrow, J. K. "The Theory of Risk Aversion." *Essays in the Theory of Risk Bearing*, ed. J. K. Arrow. Chicago: Markham Publishing Co., 1971, pp. 90–120.

Batra, R. "Resource Allocation in a General Equilibrium

· Model of Production Under Uncertainty." *J. Econ. Theory* 8(1974):50–63.

Feder, G. "The Impact of Uncertainty in a Class of Objective Functions." *J. Econ. Theory* 16(1977):654–63.

———. "Pesticides, Information, and Pest Management Under Uncertainty." Washington, D.C., World Bank Develop. Res. Ctr. Disc. Pap. No. 27, 1978.

Feder, G., and U. Regev. "Biological Interactions and Environmental Effects in the Economics of Pest Control." *J. Environ. Econ. and Manage.* 2(1975):75–91.

Gutierrez, A. P. Associate professor of Entomology, University of California at Berkeley, personal communications, 1978.

Hall, D. C. "The Profitability of Integrated Pest Management: Case Studies for Cotton and Citrus in the San Joaquin Valley." *Bull. Entomol. Soc. America* 23(1977a):267–74.

———. *An Economic and Institutional Evaluation of Integrated Pest Management.* Washington, D.C.: EPA Report 68-01-2982, 1977b.

Hall, D. C., and R. B. Norgaard. "On the Timing and Application of Pesticides." *Amer. J. Agr. Econ.* 55(1973):198–201.

Headley, J. C. "Defining the Economic Threshold." *Pest Control Strategies for the Future.* Washington, D.C.: National Academy of Sciences, 1972, pp. 100–08.

Hueth, D., and U. Regev. "Optimal Agricultural Pest Management with Increasing Pest Resistance." *Amer. J. Agr. Econ.* 56(1974):543–51.

Langham, M. R., and W. F. Edwards. "Externalities in Pesticide Use." *Amer. J. Agr. Econ.* 51(1969):1195–1201.

Norgaard, R. B. "The Economics of Improving Pesticide Use." *Ann. Rev. Entomol.* 21(1976):45–60.

Regev, U., A. P. Gutierrez, and G. Feder. "Pests as a Common Property Resource: A Case Study in Alfalfa Weevil Control." *Amer. J. Agr. Econ.* 58(1976):186–97.

Rothschild, M., and J. Stiglitz. "Increasing Risk I: A Definition." *J. Econ. Theory* 2(1970):225–43.

Shoemaker, C. "Optimization of Agricultural Pest Management II. Formulation of a Control Model." *Math. Biosci.* 17(1973a):357–65.

———. "Optimization of Agricultural Pest Management III. Results and Extensions of a Model." *Math. Biosci.* 18(1973b):1–22.

Talpaz, H., and I. Borosh. "Strategy for Pesticide Use: Frequency and Applications." *Amer. J. Agr. Econ.* 56(1974):769–75.

Taylor, C. R., and J. C. Headley. "Insecticide Resistance and the Evaluation of Control Strategies for an Insect Population." *Can. Entomol.* 107(1975):232–42.

Graduate Students from Less Developed Countries: The Continuing Demand for U.S. Training

Russell Stevenson

Four years ago, in June 1974, the writer compiled information on the enrollment of LDC graduate students in U.S. university departments of economics and agricultural and resource economics covering five academic years, 1969–73 (*AJAE*).

The 1974 survey revealed without question that a significant percentage of graduate students studying in fields related to the economics of agriculture comes from LDC countries. Among the fifty-five departments in that five-year period, there were a total of 5,094 entering graduate students of whom 1,480 or 29.05% came from eighty LDC countries. In some departments the percentage of LDC students was higher than 50%. The presence of such a large number of LDC students in U.S. graduate programs underscores the importance of efforts to strengthen their professional training within the host departments.

Early in 1978 the International Committee of the American Association of Agricultural Economics (AAEA) set in motion a further study of U.S. training and related research activities for LDC students with special funding from the Agency for International Development. The primary target group was the network of Land Grant Universities—including the 1890 colleges—with departments of agricultural, food, resource, and applied economics, including those universities where agricultural economic interests are subsumed within a single department of economics. We also included a sample of private university economics departments where international agricultural economic interests are served.

Russell Stevenson is secretary-treasurer of the Agricultural Development Council.

General Observations

The graduate program (M.S., Ph.D., nondegree) is noted only at the point of entry. It may reasonably be assumed that significant numbers of LDC students who enter a graduate program at the master's level continue into or through the Ph.D. (table 1).

Only the major source of financial support is noted even though some LDC students receive financial assistance from more than one source (table 2).

An effort was made in the second survey to identify those Western graduate students (U.S., Canada, U.K., Europe, and Australia) who upon completion of their programs had given evidence of a major interest in international agricultural economic development (table 1). The AAEA's International Committee as well as international donor organizations are concerned to know what portion of the emerging agricultural and resource economics professional community is disposed to work on international problems.

This particular total, 410 individuals representing 13.2% of the 3,087 non-LDC group over the four years, should be viewed skeptically. It was evident in correspondence and phone conversations with a number of department chairmen that this category of students is difficult to capture. The survey provided no clear formula for identifying those West-

Table 1. Numbers of Students in Forty-eight Departments

	1974–75	1975–76	1976–77	1977–78	Totals
All entering graduate students	1,006	1,200	1,148	1,155	4,509
LDC entering graduate students	356	342	360	364	1,422[a]
LDC M.S. students	209	216	226	251	902[b]
LDC Ph.D. students	142	120	126	105	493[c]
LDC nondegree students	5	6	8	8	27[d]
Westerners graduating with major interest in international agricultural economic development	114	104	89	103	410[e]

[a] The LDC group (1,422) represents 31.5% of all entering graduate students.
[b] Of the LDC group, 63.4% enrolled at master's level.
[c] Of the LDC group, 34.6% enrolled at Ph.D. level.
[d] Of the LDC group, 2% enrolled in nondegree programs.
[e] Among the non-LDC graduate students, 13.2% (3,087) indicate a major interest in international agricultural economic development.

Table 2. 1,422 LDC Students' Distribution by Sources of Financial Support, 1974–1977

Agency		Number	Percentage of Total LDC Group
U.S. government agencies		266	19
AID	252		
USDA	9		
Fulbright	5		
Foreign government agencies		312	22
U.S. universities		242	17
Foundations and nonprofit agencies		175	12
Intergovernmental agencies		54	4
FAO	10		
United Nations	25		
World Bank	9		
OAS	8		
NATO	1		
Inter-Amer. Bank	1		
Self-support		367	26
Not indicated		6	
Total		1,422	100

ern students with a "major" interest in agricultural economic development.

Finally, in table 3, one notes the distribution of LDC students by universities. They are spread across the United States. Universities in the far West have the largest numbers enrolled, whereas universities located in the South have, as a group, the highest percentage of LDC students enrolled.

Table 3. Distribution in Departments of Agricultural Economics or Economics by Universities of All Entering Graduate Students and Percentage from LDC, 1974–77

University	Entering LDC Graduate Students	Percentage of LDC Students as Total Entering Graduate Students
Vanderbilt	123	90
Tennessee St.	28	70
W. Virginia	29	57
Utah St.	58	53
Wisconsin	55	48
Yale	75	42
Ohio St.	50	40
Arizona	32	40
Colorado St.	43	38
Oklahoma St.	34	38
Hawaii	24	38
Tennessee	33	37
Idaho	7	37
Mississippi St.	16	36
Iowa St.	62	35
Pennsylvania St.	24	34
Cal./Davis	33	33
Stanford	17	33
Nebraska	15	33
Chicago	84	32
Kentucky	28	32
Illinois	43	31
Florida	38	30
Oregon St.	66	29
Washington St.	55	28
Michigan St.	40	28
Purdue	39	28
Kansas St.	23	28
Louisiana St.	9	28
North Carolina St.	43	27
Minnesota	32	27
Cal./Berkeley	14	27
Auburn	7	20
Wyoming	4	20
Texas A&M	42	19
Massachusetts	7	19
Missouri	18	18
Cornell	17	17
Vermont	2	17
Maryland	17	14
Georgia	7	14
Nevada	4	09
So. Dakota St.	4	09
Arkansas	3	09
Harvard	10	08
Maine	4	08
Montana St.	4	08
New Hampshire	0	
Totals	1,422	

Trends

I conclude with some thoughts regarding significant trends that emerge over the nine-year period covered by the two surveys:

There is a continuing strong demand for graduate level training in U.S. departments of agricultural and resource economics as measured by the total number of entering graduate students. The average annual number of entering graduate students during the five-year period from 1969–73 at the fifty-five responding departments was 1,018. During the second period, 1974–77, the average number of entering students at forty-eight responding departments increased to 1,127.

The demand is strong among LDC students. Their percentage of the total entering student group ranged from 26.6% in 1969 to 35.3% in 1974. Their enrollment increased in absolute terms from 269 at fifty-five departments in 1969 to 364 at forty-eight departments in 1977.

The percentage of LDC students entering M.S.-level programs exceeds that of the Ph.D.-entering group by a large margin (table 1). This trend is contrary to the expectations of many in the development profession (AID personnel, donor and foundation representatives, U.S. faculty), who four years ago predicted a reverse trend in their review of U.S. training (Schertz, Stevenson, Weisblat, p. 32). In a report presented to the AAEA in August 1974, it was predicted that over the next decade

Table 4. 1,422 LDC Students' Distribution by 87 Countries of Origin, 1974–77

Asia		Africa		Middle East		Latin America	
Afghanistan	14	Benin	1	Egypt	15	Antigua	1
Bangladesh	19	Botswanna	2	Greece	13	Argentina	12
Cambodia	2	Cameroun	7	Iran	106	Bahamas	3
Hong Kong	9	Cayman Islands	1	Iraq	10	Bolivia	2
India	45	Ethiopia	50	Israel	18	Brazil	71
Indonesia	35	Ghana	34	Italy	1	Chile	22
Japan	32	Ivory Coast	14	Jordan	6	Colombia	29
Korea	46	Kenya	10	Lebanon	8	Costa Rica	7
Laos	3	Lesotho	4	Libya	14	Cuba	1
Malaysia	60	Liberia	15	Malta	1	Dominican Republic	14
Micronesia	1	Mali	3	Morocco	2	Ecuador	7
Nepal	9	Nigeria	70	Portugal	2	El Salvador	8
Pakistan	35	Rhodesia	2	Saudi Arabia	16	Jamaica	5
Philippines	44	Senegal	3	Spain	6	Guyana	3
Singapore	2	Sierra Leone	8	Sudan	19	Guatemala	3
Vietnam	10	Somali	1	Syria	1	Haiti	1
Sri Lanka	2	S. Africa	3	Tunisia	13	Honduras	8
Taiwan	60	S.W. Africa	1	Turkey	18	Mexico	52
Thailand	93	Swaziland	2			Nicaragua	23
		Tanzania	21			Panama	7
		Togo	1			Paraguay	2
		Uganda	11			Peru	17
		Volta	3			Trinidad	3
		Zaire	13			Uruguay	21
		Zambia	2			Venezuela	28
Totals	521 (36.6%)		282 (19.8%)		269 (19.0%)		350 (24.6%)

there would be a decrease in the demand for M.S. degree training in the United States as LDC institutions developed local capacity to train their own students at least at the M.S. level and in some cases at the Ph.D. level. Such local graduate training capacity is emerging most notably in Asia and in Latin America.

It was assumed that LDC students would more and more take their master's level training at home or in a select number of regional training centers, and that those who came to the United States would primarily enroll in Ph.D. degree programs. Clearly, this has not been the case.

Similarly, the nondegree option for the pre-Ph.D. student has not been exercised by any significant number (less than 2%), contrary to earlier expectations (table 1).

Over the past four years, the percentage of LDC students coming from Africa and the Middle East has increased relative to the percentage coming from Asia and Latin America. In absolute terms, the largest number continue to come from Asia and Latin America in that order (table 4).

Over the period in review the sources of financial support for LDC graduate students have shifted. There has been a marked decrease in available funds from U.S. government agencies, foundations, and the universities themselves. Nevertheless, LDC students continue to come in increasing numbers with the funding gap on the U.S. side being bridged by increased funding from foreign government agencies and from LDC students' own resources.

In the 1974–77 period, 733 of a total of 1,422 LDC graduate students (52%) were funded from non-U.S. sources. This is an increase of 16% during the past four years. Only a small percentage over the nine years was funded by intergovernmental agencies.

[*Received July 1978; revision accepted September 1978.*]

References

Schertz, L. P., A. R. Stevenson, and A. M. Weisblat, eds. *International Training in Agricultural Economic Development*. New York: Agricultural Development Council, 1976.

"U.S. Graduate Students from Less Developed Countries." *Amer. J. Agr. Econ.* 56(1974):816–18.

An Economic Evaluation of Alternative Peanut Policies: Comment

James N. Trapp

In their August 1976 *Journal* article, Nieuwoudt, Bullock, and Mathia conclude that if the current peanut support price-acreage allotment program were abolished, peanut production would increase, peanut prices would fall, and gross revenue received from peanut production would rise. Bullock, Nieuwoudt, and Pasour in their May 1977 article repeat this conclusion and elaborate upon the land rental impacts associated with abolishing the peanut support price-acreage allotment program (hereafter referred to as SP-AA program). This elaboration is conducted by developing four theoretical cases which encompass the potential effects of alternative price support-acreage allotment programs upon land rent.

This comment will present theoretical arguments and historical data to show that 1973, the year for which Nieuwoudt, Bullock, and Mathia's study of the peanut SP-AA programs is based, is historically atypical for the peanut market. Because of this, Nieuwoudt's peanut policy conclusions may be misleading. Policy conclusions believed to be most consistent with typical historical peanut market conditions are that if the peanut SP-AA program were abolished, and barring unusually high demand for peanuts as experienced in 1973 and 1974, peanut production would decline, peanut prices received by farmers would fall, and gross farm income would decline. Additionally, the land rent implications associated with Bullock, Nieuwoudt, and Pasour's Case 2 (and not Case 3, as they indicate) would apply in the case of peanuts.

The Theoretical Model

The traditional supply-demand model used to illustrate the effects of SP-AA programs with some added considerations will be used to show the conditions required for Nieuwoudt's conclusions to follow versus the alternative argued here. (Several of the added considerations or modifications adopted were based upon suggestions offered by an anonymous reviewer.) The model is presented in figure 1 and depicts the case for which Nieuwoudt's conclusions follow. The support price (P_S) is set above the equilibrium price (P_E) which is determined by the intersection of the private sector demand curve (D_1) with the long-run supply curve (LS). Total private sector and public sector demand is given by D_2. The production level under the SP-AA program is depicted by Q_A, and in this case is less than Q_E, the long-run equilibrium level of production. For this case, the opportunity cost of an additional marginal unit of production is P_O and is less than P_E. Furthermore, P_A, the free market price obtainable for allotment production quantity Q_A, is above P_E.

The relationship between P_A, P_E, and P_O is critical to the conclusion that eliminating the SP-AA program will lead to expanded production as contended by Nieuwoudt and an increase in pure land rent offsetting some of the loss in allotment rent as contended by Bullock. Point *b* in figure 1 is the only historically observable point on the private demand curve; it reflects sales to private buyers at the support price. If private demand is distinctly less elastic than pictured by D_1 or if the curve lies substantially to the left of the one pictured, the equilibrium quantity will be less than the allotment quantity Q_A. It follows that Q_A would be to the right of Q_E, both P_E and P_A will be less than P_O, and the ordering of

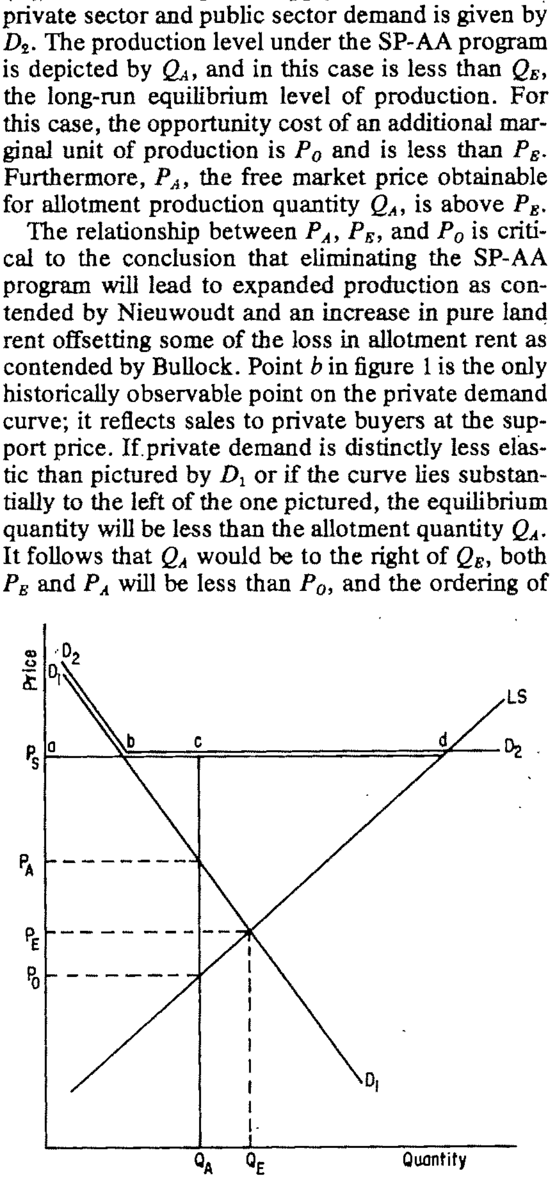


Figure 1. Modified traditional supply/demand illustration of the effects of a support price-acreage allotment program

---

James N. Trapp is an assistant professor in the Department of Agricultural Economics at Oklahoma State University, Stillwater.

Journal Article No. 3496 of the Oklahoma Agricultural Experiment Station.

The author wishes to acknowledge the helpful suggestions of Daryll E. Ray and an anonymous reviewer.

prices will be $P_O > P_E > P_A$. Hence, to substantiate the alternative conclusions argued here, that if the peanut program were abolished, peanut production would decline, peanut prices received by farmers would fall, and gross farm income would decline, it is necessary to show that the typical case in the peanut market is one where P_O exceeds P_E or, alternatively, that P_O exceeds P_A. It will be argued that Nieuwoudt, Bullock, and Mathia did not find this relation because they considered a period during which an atypical demand situation existed for peanuts.

Estimated and Observed Peanut Market Conditions

Two peanut demand models, U.S. Department of Agriculture (USDA) cost of production estimates, and historical oilseed market data are used to determine whether $P_O > P_A$ is the typical situation for the peanut market (since P_E must lie between P_O and P_A when they differ, it follows that when $P_O > P_A$ then $P_O > P_E > P_A$ is also the case).

Peanut Demand Estimates

An estimate of the price at which production on allotted acreage would sell in an open or unsupported market is required to determine P_A. The demand component of Nieuwoudt, Bullock, and Mathia's model could not be recreated successfully to make this estimate. However, estimates were available or could be generated from two other peanut demand models (Fleming and White; Song, Franzmann, Mead). Estimates of the open market clearing prices for actual peanut production levels between 1970 and 1976 as made from these models are reported in table 1, columns 4 and 5.

Production Cost and Peanut Supply

Obtaining realistic estimates of the long-run supply curve is difficult. Acreage controls for peanuts over the past twenty years have prevented significant aggregate production adjustments and, hence, cause the use of traditional econometric methods for estimating long-run supply response to be inappropriate. Cost of production estimates for the firm, therefore, must be used to glean any possible information available about the long-run supply curve.

The theory of firm behavior in a perfectly competitive market specifies that the cost of the resources used to produce a given quantity of peanuts will be bid into equality with their opportunity value in producing other products. Hence, the market value of the resources used to produce peanuts theoretically will equal P_O. The rental value of a unit of peanut allotment (R) in a perfectly competitive market will be bid upward until $P_O + R = SP$ or, verbally stated, total cost of production, including the allotment rental value, is equal to the market price received for peanuts, i.e., in this case the support price.

The perfectly competitive case is the basis for both Bullock and Nieuwoudt's work. Bullock argues that $SP - P_O = R$. Nieuwoudt uses current average cost of production data and a linear programming framework to describe supply response. Therefore, unless special considerations are taken, such as separable programming, polyperiod programming, etc., constant marginal cost of production and perfectly competitive adjustments are assumed. Under these assumptions, the long-run equilibrium price found will equal the average cost of production.

In actuality, the market for peanut-producing resources is less than perfectly competitive, particu-

Table 1. Historical Oilseed Price Data and Estimated Peanut Production Costs and Unsupported Market Value per Pound, 1970–76

	Historical Oilseed Prices			Estimated Unsupported Market Prices for Allotment Production		
Year	Soybeans	Cottonseed	Peanut Support	Song, Franzmann, and Mead Model P_A	Fleming and White Model[a] P_A	Estimated Total Cost of Production P_O
	(1)	(2)	(3)	(4)	(5)	(6)
1976	12.2	5.2	20.7	12.33[b]	13.21	14.8
1975	8.2	4.9	19.7	8.00[b]	9.62	14.1
1974	11.1	6.8	18.3	11.82[b]	11.26	11.2
1973	9.5	5.0	16.4	9.87[b]	9.88	9.7
1972	7.3	2.5	14.3	7.19	6.41	8.7
1971	5.0	2.8	13.4	5.65	7.07	8.2
1970	4.7	2.8	12.8	5.23	6.33	7.9

[a] Fleming and White did not solve their model to determine open market prices; however, their model can be placed in a solution procedure which enables it to be solved for open market prices.

[b] These values were obtained by updating the exogenous values for Song, Franzmann, and Mead's model and solving their model for 1973–76.

larly for peanut allotment rights. Peanut allotments can be transferred only by rental agreements between producers in a given county. Therefore, production cost over time would tend to be bid to local competitive equilibrium values and would be restricted from complete equilibrium. If the allotment distribution is such as to hold inefficient producers in production, the cost of peanut production with the SP-AA program may exceed the perfectly competitive cost of production for the same quantity of peanuts. Likewise, since the transfer of peanut allotments is restricted, it is likely that the rental value of peanut allotments may not be bid to the full difference between support prices and the cost of production ($SP - P_O$).

With these reservations in mind, USDA national average costs of production estimates for peanuts will be used to approximate P_O. These estimates appear in table 1, column 6. Estimates for 1974–76 are taken directly from the USDA (USDA-ERS Report to the Senate Committee on Agriculture and Forestry). Land charges used in the total cost of production calculations reported here are based on the average current value of land in peanut-producing areas and, therefore, are largely exclusive of the effect of peanut allotment rentals upon land price since peanut acreage constitutes a small percentage of the land used in these areas. Estimates for 1970–73 were obtained by backward extrapolation of national data based upon local peanut budgets for 1970–73.

Summary and Implications

Given the information developed and recorded in table 1 concerning the cost of producing peanuts and the demand for peanuts, the disequilibrium situation created by the current peanut SP-AA program can be described. A review of table 1 reveals that the relationship between the estimated cost of production (P_O in column 6) and the estimated market price (P_A in columns 4 and 5) at which production on allotted acres would have sold varies depending on the year. During 1970–72 and again in 1975 and 1976, the estimated market price for the quantity of peanuts produced under allotments (P_A) was below the production cost (P_O). It follows from theory and figure 1 that as long as production cost exceeds market price the production level must be in excess of the equilibrium level.

In 1973 and 1974, however, the estimated market price for peanuts produced on allotted acres exceeded the production cost. A temporary shift in peanut demand during 1973 and 1974 is the apparent cause for the relationship between P_A and P_O reversing from the "typical case" observed in five of the seven years from 1970 to 1976. These two years are believed to be atypical with respect to peanut demand levels because of the shortages of high protein feeds (which are produced from crushed peanuts and other crushed oilseeds) which occurred during these years. This caused a general rise in oilseed prices (see table 1, columns 1 and 2, which list soybean and cottonseed prices) which in turn caused the demand for crushed peanuts to increase dramatically. Nieuwoudt, Bullock, and Mathia's peanut demand model, as well as Fleming and White and Song, Franzmann, and Mead's demand models referred to in table 1, all use soybean or cottonseed price variables as shifters of crushed peanut demand. Hence, the recorded rises in oilseed prices during 1973 and 1974 are reflected in these models by upward shifts in crushed peanut demand and higher estimated open market peanut prices.

The upward shift in peanut demand occurring during 1973 and 1974 due to higher oilseed prices is depicted in figure 2 by the relationship between D_T (typical demand) and $D_{73,74}$ (demand in 1973 and 1974). The data in table 1 indicate that this shift was large enough to cause $P_{A73,74}$ to exceed P_O. It follows that if the 1973–74 demand conditions were sustained and the SP-AA program for peanuts were abolished, Nieuwoudt's conclusions as stated in his August 1976 article would hold, i.e., peanut prices would fall, peanut production would rise and given the nature of the peanut demand curve estimated by Nieuwoudt farm revenue from peanut sales would increase. However, if more "typical" historical demand conditions returned and the SP-AA program were abolished, Nieuwoudt's policy conclusions essentially would be reversed, i.e., production would decline, peanut prices would fall below the support price, and farm revenue from the sale of peanuts would decline.

It is also discernible from figure 2 that for typical demand conditions Bullock's land rent Case 2

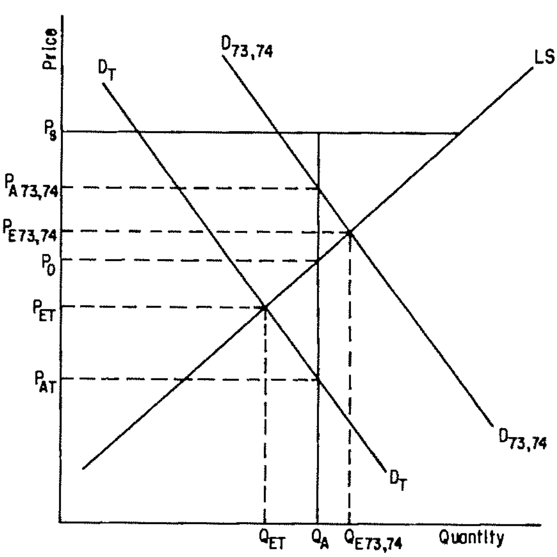


Figure 2. Alternative peanut demand conditions

where $P_S > P_O > P_E$ is applicable. Only in 1973 and 1974, when abnormally high demand for peanuts existed, is Case 3 (which Bullock selects as descriptive of the peanut market) the appropriate model.

Whether the year 1973, which appears atypical in a historical sense, will remain atypical in relation to future peanut market conditions is a separate but important question in peanut policy considerations. Demand for United States peanuts appears to have begun to strengthen again in 1976 and has continued to strengthen during 1977. In light of the relationships developed in this comment, it is hoped that Nieuwoudt's peanut model, which appears to be technically and structurally correct, would be reexamined for case years other than 1973 and for alternative scenarios of the future before policy decisions are made based upon its results.

[*Received December 1977; revision accepted May 1978.*]

References

Bullock, J. B., W. L. Nieuwoudt, and E. C. Pasour, Jr. "Land Values and Allotment Rents." *Amer. J. Agr. Econ.* 59(1977):380–84.

Fleming, F. N., and F. C. White. "Marketing Quotas as an Alternative to the Present Price Support Program for Peanuts." *S. J. Agr. Econ.* 8(1976):91–99.

Nieuwoudt, W. L., J. B. Bullock, and G. A. Mathia. "An Economic Evaluation of Alternative Peanut Policies." *Amer. J. Agr. Econ.* 58(1976):485–95.

Song, I., J. R. Franzmann, and J. T. Mead. "The Impact of the Direct Peanut Price Support Program on Farm Income and Government Cost." *S. J. Agr. Econ.* 7(1975):247–52.

U.S. Congress, Senate, Committee on Agriculture and Forestry. *Costs of Producing Selected Crops in the United States—1975, 1976, and Projections for 1977.* USDA, ERS, 1977.

U.S. Department of Agriculture. *Fats and Oils Situation.* ERS, various dates.

Resource Allocation and Risk: A Case Study of Smallholder Agriculture in Kenya: Comment

Douglas L. Young

In the November 1975, issue of this *Journal*, Wolgin presented a model of resource allocation by a multiple product firm operating under uncertainty. He tested this model with a set of data from Kenya. This comment identifies a critical mathematical error in Wolgin's theoretical derivation and shows how this error invalidated a portion of his empirical analysis. The comment also presents the correct hypothesis from Wolgin's model and discusses its economic implications.

The Model

Wolgin relied on the familiar decision criterion under risk of maximizing expected utility. He further assumed normally distributed net income (Y) making it possible to express expected utility as a function of only the mean and variance of income, or, following his notation:

$$E[U(Y)] = U^*(Y_e, \sigma_y^2). \tag{1}$$

Other assumptions included positive marginal utility of income and risk aversion, or formally, $(\partial U^*/\partial Y_e) = U^*_1 > 0$ and $(\partial U^*/\partial \sigma_y^2) = U^*_2 < 0$. This comment makes explicit the added assumption, implicit in Wolgin's derivation, of a positive marginal contribution to income variance of expanded production of any output.

For the two-crop case used, the objective function for Wolgin's model was

$$\begin{aligned} Z = {} & U^*[(P_1Q_1^e + P_2Q_2^e - X_1 - X_2), \\ & (P_1^2Q_1^{e2}\sigma_1^2 + P_2^2Q_2^{e2}\sigma_2^2 \\ & + 2P_1P_2Q_1^eQ_2^e\sigma_{12})] \\ & + \lambda_1[Q_1^e - g(F_1, X_1)] \\ & + \lambda_2[Q_2^e - h(F_2, X_2)] \\ & + \lambda_3(F_t - F_1 - F_2), \end{aligned} \tag{2}$$

where $P_iQ_i^e$ is expected price times expected output of crop i, $i = 1, 2$; X_i is value in shillings of variable purchased inputs, X, allocated to crop i, $i = 1, 2$; $P_i^{e2}Q_i^{e2}\sigma_i^2$ is variance of total revenue from crop i, $i = 1, 2$; $P_1P_2Q_1^eQ_2^e\sigma_{12}$ is covariance of total revenue from crops 1 and 2; F_i is quantity of family-owned inputs, F, allocated to crop i, $i = 1, 2$; F_t is total availability of family-owned inputs; Q_1^e is $g(F_1, X_1)$ and Q_2^e is $h(F_2, X_2)$, production functions for expected output; and λ_k's are Lagrangean multipliers, $k = 1, 2, 3$. The two arguments of U^* are simply expected net income (Y_e) and variance of net income (σ_y^2) in expanded form.

By maximizing (2) with respect to the nine choice variables, (Q_1^e, Q_2^e, F_1, F_2, X_1, X_2, λ_1, λ_2, λ_3), and eliminating the λ_k's, the initial nine first-order conditions were condensed to the following six equations:

$$\begin{aligned} U^*_1P_1 + (U^*_2)(2P_1^2Q_1^e\sigma_1^2 \\ + 2P_1P_2Q_2^e\sigma_{12}) - U^*_1/g_2 = 0, \end{aligned} \tag{3}$$

$$\begin{aligned} U^*_1P_2 + (U^*_2)(2P_2^2Q_2^e\sigma_2^2 \\ + 2P_1P_2Q_1^e\sigma_{12}) - U^*_1/h_2 = 0, \end{aligned} \tag{4}$$

$$g_1h_2 - g_2h_1 = 0, \tag{5}$$

$$Q_1^e - g(F_1, X_1) = 0, \tag{6}$$

$$Q_2^e - h(F_2, X_2) = 0, \text{ and} \tag{7}$$

$$F_t - F_1 - F_2 = 0. \tag{8}$$

In the preceding equations, U^*_i, g_i, and h_i denote the first derivatives of the respective functions with respect to their ith arguments.

Error, Corrected Derivation, and Theoretical Implications

The critical error in Wolgin's derivation occurred at the step, listed as equation (12) in his article, where, upon rearranging terms of equations (3) and (4) above and taking their ratio, he erroneously concluded that

$$\frac{P_1g_2 - 1}{P_2h_2 - 1} = \frac{2P_1^2Q_1^e\sigma_1^2 + 2P_1P_2Q_2^e\sigma_{12}}{2P_2^2Q_2^e\sigma_2^2 + 2P_1P_2Q_1^e\sigma_{12}}. \tag{9}$$

The correct ratio, as the reader can confirm, is

$$\frac{P_1g_2 - 1}{P_2h_2 - 1} = \frac{(2P_1^2Q_1^e\sigma_1^2 + 2P_1P_2Q_2^e\sigma_{12})g_2}{(2P_2^2Q_2^e\sigma_2^2 + 2P_1P_2Q_1^e\sigma_{12})h_2}. \tag{10}$$

What are the economic implications of this correction? Observe initially that the right hand side of (10) is equal to

$$\frac{(\partial\sigma_y^2/\partial Q_1^e)(\partial Q_1^e/\partial X_1)}{(\partial\sigma_y^2/\partial Q_2^e)(\partial Q_2^e/\partial X_2)} = \frac{\partial\sigma_y^2/\partial X_1}{\partial\sigma_y^2/\partial X_2}. \tag{11}$$

The term, $\partial\sigma_y^2/\partial X_i$, represents the marginal incre-

---

Douglas Young is an assistant professor of agricultural economics and assistant agricultural economist at Washington State University.

This is Scientific Paper No. 4957 of the Washington State University College of Agriculture Research Center.

Helpful comments by Lars Brink and Ron Mittelhammer on an earlier draft of this paper are gratefully acknowledged.

ment to risk of an additional unit of purchased inputs, X, applied to the ith crop.[1]

Note that in order to form the ratio in (10), (3) and (4) are transformed to

$$(12)\quad P_1g_2 - 1 = -(U^*_2/U^*_1)(2P_1^2Q_1^e\sigma_1^2 + 2P_1P_2Q_2^e\sigma_{12})g_2, \text{ and}$$

$$(13)\quad P_2h_2 - 1 = -(U^*_2/U^*_1)(2P_2^2Q_2^e\sigma_2^2 + 2P_1P_2Q_1^e\sigma_{12})h_2.$$

Under the prevailing assumptions of $U^*_1 > 0$, $U^*_2 < 0$, positive marginal physical products, and $\partial\sigma_y^2/\partial Q_i^e = (2P_i^2Q_i^e\sigma_i^2 + 2P_1P_2Q_j^e\sigma_{12}) > 0$ for i and $j = 1, 2$, and $j \neq i$, both sides of (12) and (13) and hence both numerators and denominators of (10) are positive. The latter conditions permit one to conclude from (10) that

$$(14)\quad P_1g_2 \gtreqless P_2h_2 \text{ as } \partial\sigma_y^2/\partial X_1 \gtreqless \partial\sigma_y^2/\partial X_2.$$

Expression (14) states that a risk averse utility-maximizing entrepreneur will require a higher expected marginal value product (MVP^e) from a given input in an application where its contribution to risk is greater.[2] This conclusion is consistent with the well-known result for the single product case (Magnusson, p. 65; Anderson, Dillon, Hardaker, p. 163) that under uncertainty and risk aversion the MVP^e of a variable input will exceed its marginal factor cost (MFC) by a (positive) "marginal risk deduction" that is proportional to the degree of risk aversion, measured by $-U^*_2/U^*_1$, multiplied by the input's (positive) marginal increment to income riskiness, $\partial\sigma_y^2/\partial X$. In fact, the result for the single product case can be derived from either equation (3) or (4) of the present model. Equation (3), for example, implies

$$(15)\quad 1 = P_1g_2 + (U^*_2/U^*_1)(2P_1^2Q_1^e\sigma_1^2 + 2P_1P_2Q_2^e\sigma_{12})g_2,$$

which equals[3]

$$(16)\quad MFC \text{ of } X_1 = MVP^e \text{ of } X_1 + (U^*_2/U^*_1)(\partial\sigma_y^2/\partial X_1).$$

Implications of Error for Empirical Analysis

Wolgin presented the empirical tests suggested by his theoretical model in tables 2 (p. 628), 3 (p. 629), and 4 (p. 630). This section shows that the error identified in the preceding section invalidates the test in table 4, that the test in table 2 is empirically correct but not for the reason asserted by Wolgin, and that the test in table 3 is sound because it did not rely on the erroneous derivation.

On the basis of the erroneous result listed in equation (9), Wolgin derived (p. 625)

$$(17)\quad P_1g_2 \gtreqless P_2h_2 \text{ as } \partial\sigma_y^2/\partial Q_1^e \gtreqless \partial\sigma_y^2/\partial Q_2^e.$$

He subsequently concluded (p. 625), "A testable corollary of this proposition is that a ranking of crops by their marginal increments to risk ($\partial\sigma_y^2/\partial Q_i^e$) should be identical to a ranking of the marginal value products of any allocatable input across crops." In table 4, Wolgin reported the results of a test based on this conclusion for forty-five crop pair comparisons. He found (p. 629) "thirty-nine exhibited behavior consonant with the model, i.e., the crop with the higher marginal value product also had the higher marginal increment to risk."

The correct result presented in equation (12), however, reveals that one would expect MVP^e's of any given input, X, across n crops to be ranked by $\partial\sigma_y^2/\partial X_i$, $i = 1, 2, \ldots, n$, and not by $\partial\sigma_y^2/\partial Q_i^e$, $i = 1, 2, \ldots, n$. The ranking of $\partial\sigma_y^2/\partial X_i$, $i = 1, 2, \ldots, n$, across n crops will not necessarily be identical to the ranking across n crops of $\partial\sigma_y^2/\partial Q_i^e$, $i = 1, 2, \ldots, n$; the rankings can differ because of the influence of the factor $\partial Q_i^e/\partial X_i$, in the product $(\partial\sigma_y^2/\partial Q_i^e)\ (\partial Q_i^e/\partial X_i) = \partial\sigma_y^2/\partial X_i$. Consequently, the rationale for Wolgin's table 4 is incorrect. Only by fortunate coincidence would one expect the hypothesized results.

In table 2, Wolgin presented evidence that MVP^e rankings across crops were similar for all inputs. He justified the analysis by arguing (p. 628) "if farmers are risk averse, the marginal value products of any inputs across crops will not be equal but will depend on the marginal increments to risk of each crop. This implies that the ranking of the marginal value products across crops will be identical for all inputs."

As shown earlier, MVP^e's for a given input across crops will be ranked identically with the marginal increments to risk of that input used in different crops ($\partial\sigma_y^2/\partial X_i$), not with the marginal increments to risk of the different crops ($\partial\sigma_y^2/\partial Q_i^e$). Accordingly, Wolgin's justification for expecting MVP^e's across crops to be ranked identically for all inputs is incorrect. MVP_e's across crops should indeed be ranked identically for all inputs due to first order condition (5) and the inequalities in (14), as shown by the proof in the appendix, but not as a consequence of (17) as implied by Wolgin. Accordingly, the empirical test in table 2 is appropriate, but for a different reason than presented by Wolgin.

The analysis reported in Wolgin's table 3 was

---

[1] This conclusion requires the assumption, implicit in Wolgin's derivation of the first order conditions, that increased utilization of input x_i induces a change only in Q_i^e among the seven arguments of the function, $\sigma_y^2 = P_1^2Q_1^{e2}\sigma_1^2 + P_2^2Q_2^{e2}\sigma_2^2 + 2P_1P_2Q_1^eQ_2^e\sigma_{12}$. The existence of perfect competition and nonjoint production processes would shield P_1, P_2, Q_j, and σ_j ($j \neq i$) from dependence upon x_i, but in many real world applications the assumptions of $\partial\sigma_i^2/\partial x_i = 0$ and $\partial\sigma_{12}/\partial x_i = 0$ would seem less defensible. For example, increased nitrogen fertilization probably modifies yield (and total revenue) variability.

[2] The reader should remember, however, that this conclusion is dependent upon the specific assumptions of risk aversion and positive marginal risk contributions ($\partial\sigma_y^2/\partial Q_i^e$'s) maintained in this study. If the decision maker were risk loving, i.e., $U^*_2 > 0$, or if $\partial\sigma_y^2/\partial Q_i^e < 0$, $i = 1, 2$, then $(P_1g_2 - 1)$ and $(P_2h_2 - 1)$ would be negative and this would reverse the direction of one of the sets of inequalities in (14). For example, in the general multiple product model a sufficiently large negative covariance of income between outputs might produce negative $\partial\sigma_y^2/\partial Q_i^e$'s.

[3] In Wolgin's model the *MFC* of an additional shilling's worth of purchased inputs is necessarily equal to one shilling. The reader can easily confirm that $P_x = MFC_x$ appears on the left-hand side of (14) when x is specified in quantity terms and is purchased for a fixed price, P_x.

theoretically sound because it relied only on the equality of expected marginal physical product ratios implied by equation (5).

Revision of Wolgin's empirical analysis in table 4 would require the computation and ranking of all input marginal risk increments, $\partial\sigma_y^2/\partial X_i$, across all outputs. The information required for this revised analysis was necessarily generated by Wolgin, although it was not presented in his published article. It would be relatively simple for Wolgin to revise his empirical analysis. Ignoring the unfortunate error in the theoretical derivation that led part of his subsequent empirical analysis astray, Wolgin's research was imaginative and well conceptualized. His study potentially provides a much needed addition to the meager stock of empirical tests of the expected utility maximizing model under uncertainty.

[*Received October 1977; revision accepted July 1978.*]

References

Anderson, J. R., J. L. Dillon, and J. B. Hardaker. *Agricultural Decision Analysis*. Ames: Iowa State University Press, 1977.

Magnusson, G. *Production Under Risk: A Theoretical Study*. Uppsala: Almqvist and Wiksells, 1969.

Wolgin, J. M. "Resource Allocation and Risk: A Case Study of Smallholder Agriculture in Kenya." *Amer. J. Agr. Econ.* 57(1975):622–30.

Appendix

Ranking of MVP^e*'s across Crops*

To prove that MVP^e's across crops are ranked identically for all inputs, it is sufficient to prove that the $\partial\sigma_y^2/\partial x_{ij}$'s, where x_{ij} denotes the ith input used in the jth crop, are ranked identically across crops for all inputs. This is true because (14) specifies that the MVP^e's and $\partial\sigma_y^2/\partial x_{ij}$'s have the same rankings across crops. A proof for the simple two-input, two-output case, which can be generalized to larger dimensions, is presented below:

THEOREM. As $Z_{11} \gtreqless Z_{12}$, $Z_{21} \gtreqless Z_{22}$, where $Z_{ij} = \partial\sigma_y^2/\partial x_{ij}$.

Proof.

(*i*) $$Z_{ij} = R_j\, MPP_{ij}$$

by the decomposition of Z_{ij} observed in the numerator and denominator of (11), where $R_j = \partial\sigma_y^2/\partial Q_j^e$ and MPP_{ij} equals the positive expected marginal physical product of the ith input in the jth product;

(*ii*) $$\frac{MPP_{11}}{MPP_{12}} = \frac{MPP_{21}}{MPP_{22}}, \text{ by (5) implies}$$

(*iii*) $MPP_{21} = K_2\, MPP_{11}$, and $MPP_{22} = K_2\, MPP_{12}$,

where K_2 is the positive factor of proportionality between MPP's of inputs 1 and 2 as determined from (*ii*);

(*iv*) $(Z_{11} \gtreqless Z_{12}) = (R_1\, MPP_{11} \gtreqless R_2\, MPP_{12})$, *by* (*i*) implies

(*v*) $(R_1\, K_2\, MPP_{11} \gtreqless R_2\, K_2\, MPP_{12}) =$

(*vi*) $(R_1\, MPP_{21} \gtreqless R_2\, MPP_{22})$
$= (Z_{21} \gtreqless Z_{22})$, by (*iii*) and (*i*).

Resource Allocation and Risk: A Case Study of Small-holder Agriculture in Kenya: Reply

Jerome M. Wolgin

In his comment on my November 1975 article, Young demonstrates an algebraic error which I made in the derivation of testable hypotheses from my model of farmer behavior under risk. He further "shows how this error invalidated most of [the] empirical analysis." I am indebted to the author for pointing out this error, for the correction which he presents in his comment makes the conclusions much more satisfying. However, I hope to show in this brief reply, that the empirical results are not changed by this correction, and that, moreover, the original results presented in my article follow logically from the corrected implications of the model and do not arise from "coincidence" as Young suggested.

In looking at the utility-maximizing conditions of farmer behavior under risk, I concluded that

$$(1) \qquad P_1 g_2 \gtreqless P_2 h_2 \text{ as } S_1 \gtreqless S_2,$$

where $P_1 g_2$ and $P_2 h_2$ are the marginal value products of a given input, e.g., labor, in crops 1 and 2, respectively; and S_1, S_2 are the marginal increments to risk of an extra unit of output of crops 1 and 2, respectively.

The correct formulation stated in general terms is

$$(2) \quad P_1 g_1 - \pi_i \gtreqless P_2 h_i - \pi_i \text{ as } S_1 g_i \gtreqless S_2 h_i \text{ for all } i,$$

where π_i is the price of the ith input. Equation (2) says that the difference between the marginal value product of any input and its price in crop 1 will be greater than, equal to, or less than the difference between the marginal value product of that input and its price in crop 2 as the marginal increment to risk of an extra unit of the input in crop 1 is greater than, equal to, or less than the marginal increment to risk in crop 2 or an extra unit of the same input.

Because $S_1 \gtreqless S_2$ for all inputs, the conclusion drawn from (1) was that for any two crops the marginal value products of all inputs would be ranked identically, and because these results are transitive, this result also would be true for all crops within an ecological zone. This was the reasoning behind the use of tables 1 and 2 as tests of the original model. What I now propose to demonstrate is that inequality (2) under certain conditions implies that these tests remain valid.

Recasting (2), we get

$$(3) \quad \frac{P_1 g_i - \pi_i}{g_i} = S_1, \text{ and } \quad \frac{P_2 h_i - \pi_i}{h_i} = S_2.$$

Thus, since $S_1 \gtreqless S_2$ for all inputs i,

$$(4) \quad \frac{P_1 g_i - \pi}{g_i} \gtreqless \frac{P_2 h_i - \pi_i}{h_i} \text{ as } S_1 \gtreqless S_2 \text{ for all } i.$$

Now assume that $g_i \geqslant h_i$ for all i and also that

$$\frac{P_1 g_i - \pi_i}{g_i} \geqslant \frac{P_2 h_i - \pi_i}{h_i},$$

then

$$(5) \qquad P_1 g_i - \pi_i \geqslant P_2 h_i - \pi_i,$$

and, therefore,

$$(6) \qquad P_1 g_i \geqslant P_2 h_i \text{ for all } i.$$

Of the twenty-seven possible comparisons of any two crops across the four ecological zones, the above assumption holds for thirteen, or 48% of them. For the other fourteen comparisons, the inequalities go in opposite directions, and there is no analytic way to show that inequality (6) follows from (4).

Nevertheless, given the relationship between inequality (2) and inequality (4), it is not surprising that the results are not appreciably changed by the correction. Table 1 presents data on the corrected average value of the marginal increment to risk of the increased production of any crop, S_i.

The revised table strengthens the original conclusion that risk plays an important role in farmer decision making in Kenya.

[*Received February 1978; revision accepted August 1978.*]

Jerome M. Wolgin is an assistant professor in the Department of Economics, Wayne State University.

Reference

Wolgin, Jerome M. "Resource Allocation and Risk: A Case Study of Smallholder Agriculture in Kenya: Reply." *Amer. J. Agr. Econ.* 57(1975):622–30.

Table 1. Marginal Increment to Risk of Agricultural Inputs in Kenya, 1969/70

Zone 3 (balanced mixed farming):

Input	Crop: Local Maize	Hybrid Maize	Pyrethrum	Improved Dairy	Unimproved Dairy
Land	22.88	25.36	0.28	1.40	1.17
Family labor	22.22	16.66	0.76	1.25	0.18
Hired labor	15.22	—	0.62	1.79	—
Purchased inputs	0.70	20.91	—	1.81	−6.36
Capital	27.50	20.95	—	1.54	−1.33
Mean	19.30	20.97	0.55	1.56	0.68[a]
Coefficient of variation	0.34	0.15	0.37	0.14	0.72

Zone 4 (Kikuyu Grass):

Input	Crop: Local Maize	Coffee	Tea	Improved Dairy
Land	−32.48	0.22	0.30	2.50
Family labor	25.00	0.27	0.30	2.48
Hired labor	−10.00	−0.20	—	—
Purchased inputs	27.55	0.23	—	2.50
Capital	28.06	—	—	—
Mean	26.87[a]	0.24[a]	0.30	2.50
Coefficient of variation	0.05	0.01	0.00	0.00

Zone 5 (Star Grass):

Input	Crop: Local Maize	Hybrid Maize	Cotton	Coffee	Unimproved Dairy
Land	−5.49	16.94	0.74	0.19	−0.45
Family labor	1.95	23.93	0.55	0.21	0.10
Hired labor	−219.04	—	—	0.18	—
Purchased inputs	2.05	20.22	—	0.08	−0.34
Capital	20.83	29.87	—	—	−0.83
Mean	8.28[a]	22.74	0.65	0.17	0.10[a]
Coefficient of variation	1.07	0.21	0.15	0.29	0.00

Zone 6 (Grass Plains, Savannah, Coastal Belt):

Input	Crop: Local Maize	Unimproved Dairy
Land	−12.13	0.34
Family labor	8.00	−1.66
Hired labor	6.09	—
Purchased inputs	19.13	0.12
Capital	25.26	1.89
Mean	14.62[a]	0.78[a]
Coefficient of variation	0.54	1.01

[a] Positive values only.

Property Rights and the Political Economy of Resource Scarcity: Comment

William Sander

In a recent article in this *Journal,* Castle discussed the interface between the economics of natural resources and property rights. He argued that externalities and unearned increments were the impetus for current challenges to private rights in property.

Castle's paper presents a good base from which a more general resource model could be developed. As Castle notes (p. 2), the market-failure body of economic theory which resource economists have drawn upon is inadequate for explaining and prescribing solutions to many resource problems. For example, the impact of the environmental movement on Bureau of Reclamation and Corps of Engineers projects goes far beyond the issue of an externality. Similarly, efforts on the part of the energy industry to promote resource development go beyond unearned increment issues. Castle calls for analyses of such problems "to be supplemented by economic analysis of particular public policies and a modicum of political science and the law" (p. 2). Several concepts that might be used for such analyses will be outlined below.

First, resource problems should be assessed in light of the political context which makes them problems and which influences public responses to them. As political scientists have demonstrated, interest group pressures help to define problems and to influence public responses. Public policy and administrative decisions tend to be in the interest of those with the most bargaining power. Holden has shown how bargaining between polluters and regulators affects the promulgation and enforcement of pollution standards. Several studies (Allee and Ingram, Ingram 1969, Sander) have shown how politics influence and may even hold sway over economic benefit-cost standards in the authorization and development of federal water projects.

Olson has developed a model that helps explain the political bargaining process. The gist of Olson's model is that the ability to achieve a collective good depends upon how much the good is valued by a group and by how many individuals there are in the group. A collective good is defined by Olson as "the achievement of any common goal or the satisfaction of any common interest" (p. 15). The greater value that a group places upon the achievement of a collective good, the greater is the probability that it will be achieved. However, the larger the size of the group, the smaller the probability that the collective good will be achieved. That is, if the group is large, individuals within the group could only achieve, perhaps, a small share of the collective good. Also, individuals within the group may perceive that they might enjoy the collective good without actively working for it. This decreases group cohesiveness and resolve and, accordingly, political influence. Thus, smaller groups are often able to bargain more effectively than larger, more diffused interests. That is, the individual stakes of the members of the smaller group may be relatively large compared to the individual stakes of the members of a larger group, even though the total value of the collective good was much greater for the larger group than for the smaller group. For this reason, a particular interest can often "win out" over a more diffused public interest. Thus, the value of a collective good and the expected distribution of the good among members of a group affect the incentive and ability to bargain in the political process.

There is an important link between this model of group behavior and Castle's contention that the distribution of income and costs will affect any redistribution of property rights (p. 7): the direct and indirect distribution of income (or benefits) and costs defines the stake that interest groups have in supporting or opposing resource investment, conservation, or regulatory decisions. Thus, even though the economic benefits to the nation may exceed the costs to the nation on a particular resource issue, certain particular interests such as an industry or region may lose. The particular interests that may lose may have veto power over the decision. Similarly, a resource issue may be in the interest of a particular group and not in the interest of a more diffused group such as the nation. In this case, the particular interest may dominate over the larger more diffused interest. For example, the literature in the field of regulatory economics has shown that regulatory agencies which are established to promote the public interest can be "captured" by the particular interests they regulate (Bernstein).

An individual or group's ability to bargain is affected by many other factors. Dahl notes (pp. 85, 225–26) that bargaining power is related to control over jobs, access to money, information, and social values, among other things. Although many factors influence political participation and bargaining

---

William Sander is an economist with the Illinois Economic and Fiscal Commission, Springfield.

capacity, the Olson model directly links economic impacts with political implications. As such, economists should find it useful.

Administrative efficiency in resource management and development is a second issue that must be assessed in a general resource model. Large jurisdictional administrative units may seem appropriate for many resource problems as Castle suggests, but large units may not resolve conflicts among competing interests. If the larger unit includes the competing interests, competition among the interests should continue even though they are part of a larger unit. For example, multistate regional water institutions have not resolved conflicts among competing state interests in water (Ingram 1973).

More generally, administrative arrangements affect the ability of government to plan and implement policy. The bias has been that more consolidated agency structures are more efficient. However, one school of thought is that fragmented, overlapping structures sometimes serve the public interest best (Ostrom, Bish and Ostrom, Bish). They argue that there are economies and diseconomies of scale to government organization as there are to firm size and that competition among many units of government sometimes helps to promote efficiency as does competition in the marketplace.

Administrative arrangements for resource management and development must also be assessed in light of impacts upon political access which affects the ability of interest groups to bargain in the political system. That is, agency structures affect the distribution of political power. Haskell and Price (pp. 252–55) have shown that state environmental superdepartments that combine pollution control functions with conservation functions can adversely affect the impact that pollution control and conservation interest groups have upon decisions. That is, the agency structure affects the relative access that both groups have.

The distribution of power between branches of government will also affect resource decisions by their impact upon access. For example, in recent years presidents have tried to shift the center of decision-making power from Congress to the president. In 1970 President Nixon through his Reorganization Plan No. 2 established a Domestic Council in the White House to determine "what Government should do" and the Office of Management and Budget (OMB) to determine "how we do it and how well we do it" (Ostrom, pp. 136–37). This reorganization has an impact on resource decisions. For example, OMB has opposed several Bureau of Reclamation projects that Congress has supported. Similarly, in 1977 the President's Domestic Council initiated an attack on several water projects that had substantial support in Congress. In both cases executive reorganization made it more difficult for Congress to authorize certain water projects.

As a final point, resource policy decisions must also be evaluated in terms of standards such as economic efficiency or social equity. Lowi has promoted this idea that government has certain functions that should be held accountable to such standards which should be incorporated into formal statements of policy (or law). Government's functions are to distribute, regulate, and redistribute, according to Lowi. Lowi also makes the point that each function (or policy type) has different attributes such that implementation requirements for one policy type differ from the requirements for another policy type. An assessment of Lowi's ideas is beyond the scope of this comment. However, his policy framework probably warrants the attention of economists who are interested in public policy.

These concerns and perhaps others must be addressed to ensure that resource decisions are linked with the efficiency and equity preferences of the polity and the public; otherwise, efforts to promote the public interest "may be counter productive or ineffective," as Castle suggests (p. 8).

[*Received April 1978; revision accepted June 1978.*]

References

Allee, David J., and Helen M. Ingram. *Authorization and Appropriation Processes for Water Resource Development.* Washington, D.C., National Water Commission Report, 1972.

Bernstein, Marver H. *Regulating Business by Independent Commission.* Princeton: Princeton University Press, 1955.

Bish, Robert L. *The Public Economy of Metropolitan Areas.* Chicago: Markham Publishing Co., 1971.

Bish, Robert, and Vincent Ostrom. *Understanding Urban Government.* Washington, D.C.: American Enterprise Institute, 1973.

Castle, Emery N. "Property Rights and the Political Economy of Resource Scarcity." *Amer. J. Agr. Econ.* 60(1978):1–9.

Dahl, Robert. *Who Governs?* New Haven, Conn.: Yale University Press, 1961.

Haskell, Elizabeth H., and Victoria S. Price. *State Environmental Management.* New York: Praeger Publishers, 1973.

Holden, Matthew. *Pollution Control as a Bargaining Process.* Ithaca, N.Y.: Cornell University Water Resources and Marine Sciences Center, 1966.

Ingram, Helen M. *Patterns of Politics in Water Resource Development.* Albuquerque, N.M.: Div. Govt. Res., University of New Mexico, 1969.

———. "The Political Economy of Regional Water Institutions." *Amer. J. Agr. Econ.* 55(1973):10–18.

Lowi, Theodore J. "Four Systems of Policy, Politics, and Choice." *Public Admin. Rev.* 32(1972):298–310.

Olson, Mancur. *The Logic of Collective Action.* Cambridge, Mass.: Harvard University Press, 1971.

Ostrom, Vincent. *The Intellectual Crisis in American Pub-*

lic Administration. University: University of Alabama Press, 1974.

Sander, William H., III. "Some Economic, Institutional, and Political Aspects of Irrigation Planning and Development: Lessons from the Bureau of Reclamation Experience." Ph.D. thesis, Cornell University, 1978.

Property Rights and the Political Economy of Resource Scarcity: Reply

Emery N. Castle

I am grateful to Sander for extending my paper in a useful way in several dimensions. I have no major disagreement with anything he says, but two brief clarifying comments seem appropriate.

My objective was not to present a general resource model. Rather, it was to call attention to current developments which are likely to trigger significant policy changes. Mass consumption and production is constantly creating new and significant external diseconomies. Resource scarcity, whether the result of demand and supply considerations or institutional constraints, will create economic rent which gives rise to distributional issues. Concern with the appropriate jurisdictional unit is also an important phenomenon. It was, and is, my belief that these three developments are of major importance on the contemporary scene. Whether I am correct or not has little to do with the utility of the considerations identified by Sander.

I have no quarrel with what Sander says about the size of jurisdictional units, although he implies otherwise. My point is that we have entrusted large units with certain problems and small units with other problems. We are now discovering that the problems are often interdependent and that the attempt to separate them leads to conflict. This issue, I believe, is very different than the kind of problem which has been investigated by Ostrom and Bish.

Again, let me express my thanks to Sander for his extensions.

Emery N. Castle is vice-president and senior fellow of Resources for the Future.

References

Bish, Robert L. *The Public Economy of Metropolitan Areas*. Chicago: Markham Publishing Co., 1971.

Castle, Emery N. "Property Rights and the Political Economy of Resource Scarcity." *Amer. J. Agr. Econ.* 60(1978):1–9.

Ostrom, Vincent. *The Intellectual Crisis in American Public Administration*. University: University of Alabama Press, 1974.

International Commodity Markets and Trade
(Robert L. Thompson, Purdue University, Chairman)

Trade Models with Differentiated Products

Paul R. Johnson, Thomas Grennes, and Marie Thursby

Why do prices differ? Although trade tends to equalize prices, some important differences persist. What is the source of the differences? For certain purposes, it may be important to distinguish two sets of prices: (*a*) the spatial distribution of prices of a given product (e.g., the prices of U.S. wheat in the United States and in the United Kingdom) and (*b*) relative prices of similar products in a common geographical market (e.g., price of U.S. wheat in the United Kingdom and the price of Canadian wheat in the United Kingdom).

The pattern of spatial prices is explained largely by transfer costs such as transport, marketing margins, and governmental trade barriers. Spatial equilibrium models have attempted to explain these price differentials by assuming that the products being traded are perceived by demanders as being homogeneous. These models, however, do not allow consumer prices of a commodity in a particular import market to vary by supplier at a given point in time. That is, the relative price of U.S. and Canadian wheat in the United Kingdom, for example, would be unity. In addition, they predict a unidirectional trade flow pattern, so that either cross-hauling of commodities between two trading countries is prohibited or the trade pattern predicted is a net trade pattern.

Why might we observe nonunitary relative prices of commodities supplied by varying countries or cross-hauling of goods? One explanation is that commodities supplied by different countries are differentiated in the eyes of importers. Product differentiation has been shown to be an important factor in international trade. Dissatisfaction with the simple Heckscher-Ohlin trade model of factor proportions has led people to emphasize demand considerations which are satisfied by product differentiation (H. G. Johnson). Grubel and Lloyd's study of intra-industry trade discussed below has shown the empirical importance of product differentiation.

Models based on product differentiation may be justified in two ways. First, one might appeal to the demand theory of Lancaster in which consumers ultimately desire product characteristics, and products can combine these characteristics in varying proportions. The protein content of wheat could be one variable in this hedonic approach to demand. An alternative approach stresses differences among suppliers rather than in product characteristics. Some suppliers may be more reliable than others and buyers may want to diversify to protect against the possibility of an embargo (Branson). If suppliers offer different contracts in terms of delivery dates, credit, or other services, prices of identical products in a simple market may vary by supplier (Kravis and Lipsey). Buyers may choose suppliers with familiar languages and institutions because they may save enough on transactions costs to outweigh an unfavorable wheat price quotation. This second approach is rather vague about the nature of differences among suppliers, but it can be made operational by assuming that perceived differences among suppliers are incorporated in historical market shares, and those shares are expected to remain constant unless relative prices or incomes change.

An alternative statement of the latter phenomenon can be made in terms of information costs and consumer search (Stigler, Telser 1962, Nelson 1970, 1974). If particular

---

The papers in the Proceedings Section were presented at the AAEA-sponsored sessions of the Allied Social Science Association's Annual Meeting, held in Chicago on 29–31 August 1978.

Paul R. Johnson is a professor and Thomas Grennes is an associate professor in the Department of Economics and Business, School of Agriculture and Life Sciences, North Carolina State University. Marie Thursby is an assistant professor of economics at Ohio State University.

This is Paper No. 5652 of the Journal Series of the North Carolina Agricultural Experiment Station, Raleigh.

suppliers are more reliable than others, then a contract for wheat delivered from the reliable suppliers is of a different quality than a contract made with less reliable suppliers. Reliability to honor contracts is only observed from the "experience" of dealing with the supplier or from obtaining such information from importers who have dealt with them. As shown by Nelson (1970), suppliers of experience goods are more likely to maintain monopoly power than those who produce "search" goods, goods whose quality can be observed in the market. That is, the number of brands (number of countries from which an importer buys) an importer samples is larger for search goods than experience goods because of the difference in the cost of search. The greater the number of searches, the lower is monopoly power of suppliers. Recently Schmalensee has presented a model of markets for experience goods in which equilibrium market shares for suppliers are a positive function of product quality. For our example, the historical market shares of traditional wheat exporters should be higher, *ceteris paribus,* than those for less reliable exporters. This result is based on a model in which suppliers charge identical prices (hence their competition is not price competition), buyers are identical, and there is no advertising (Schmalensee).

In spite of the demonstrated importance of product differentiation for manufactured goods, it generally is presumed to be less important for agricultural products (Black, Isard). A notable exception of this presumption is Richardson (1978). This presumption is based on the view that product differentiation is a function of characteristics of the product in use. According to the alternative approach, even for functionally homogeneous agricultural products, the power of governments over [illegible]

would show two-way trade in the same product and price differentials which differed from transfer costs, even though in each six-month period international price differences were exactly equal to transfer costs.

Moreover, prices of a homogeneous good may vary by source of supply because of costs of obtaining information about prices. Telser (1973) has considered models in which the existence of information costs will generate a distribution of prices even when all consumers have identical preferences and the products are homogeneous. The study of search costs has been motivated by the observation that sampling labor and product markets in a given city rarely results in a single price quotation (Stigler). In fact, where the range of the distribution of prices of a homogeneous good is small, Telser finds the marginal return of searching over suppliers to be so small relative to the marginal cost of search that an equilibrium distribution of prices persists. Thus, there are a priori reasons to expect spatial price differences because of transfer costs and time aggregation, and to expect price differences among similar products in the same market because of product differentiation, information costs, and aggregation of data.

Evidence on Prices

Orcutt in a classic work outlined several reasons why empirical estimates of elasticities in international trade would be too low. A great deal of effort went into examining both data and technical econometric techniques in the fifties and sixties to correct this situation. On a priori grounds, an estimate such as Turnovsky's estimate that the elasticity of demand for [illegible]

timated indicate the goods can be considered differentiated.

Three studies done by Capel, Reekie, and Sirhan in the 1960s are summarized by Johnson (1971). These studies start with the presumption that the commodities involved—tobacco, wheat, and cotton—are not homogeneous. The products of various countries are differentiated by quality and other inherent features, contractual obligations, location of processing facilities, custom, and other things. Employing the elasticity of substitution model of Harberger, Reekie, for instance, could conclude that even U.S. and Canadian wheat are not perfect substitutes in third markets. Flue-cured tobacco is a good example of a product that turns out to be nonhomogeneous, with the U.S. price substantially higher in foreign markets than competing products. Capel found point estimates of the elasticity of substitution of U.S. versus all other exporters to the United Kingdom, West Germany, and Benelux of −2.92 and −3.92. Again, the implication of heterogeneity is clear.

In the cotton study, Sirhan looked at two models, both of which imply nonhomogeneity between countries. He employed the elasticity of substitution model and then a market share model patterned after one of Telser (1962). With perfect information, homogeneous products should imply market shares that go to zero or one if price differences persist. The elasticities of market share for U.S. cotton in the United Kingdom and West German markets were large (−3 to −9), but they by no means implied that either market failed to differentiate cotton by its place of origin.

In our own work on grains (Grennes, Johnson, Thursby 1978a), we did some limited calculations of elasticities of substitution. For wheat we reconfirmed Reekie's results for the most part. Collins (1977) also found substantial evidence for nonhomogeneity in coarse grains. The latter result is more predictable on a priori grounds than is wheat.

There have been numerous studies that have estimated elasticities of substitution of aggregate exports and imports and of manufactures. Much of this literature is not concerned with the product differentiation issue. A large part of it concerns whether the elasticity of substitution can be used as an indirect way to estimate the elasticity of demand for a country's exports (for varying levels of aggregation). This issue is summarized and tested in Richardson (1973).

The IMF models of Armington and others, as well as certain models developed for Project Link also employ substitution elasticities directly into the basic demand relationships. These models are designed to deal with goods differentiated by country of origin.

Grubel and Lloyd, mentioned above, attack the problem of product differentiation head on. Their fundamental concept is intra-industry trade. When one leaves the pure theory of trade and goes to the data, one observes a large amount of trade for particular countries that represents both exports and imports of the same commodity. These cross-hauls are netted out for many empirical applications. This leaves a large part of the world's trade unexplained. An example that we have treated elsewhere is the need to explain why the European Community (EC) simultaneously imports and exports wheat. This observation is consistent with Grubel and Lloyd's observation that intra-industry trade is observed for even the finest breakdowns of larger aggregates.

The major inference emphasized by Grubel and Lloyd is that the observed intra-industry trade is not an empirical refutation of the Heckscher-Ohlin trade theory. Intra-industry trade should be taken as evidence that some of the assumptions underlying strict Heckscher-Ohlin predictions are too stringent for the real world. They point out that even for functionally homogeneous goods one can observe intra-industry trade by reason of transfer costs such as transportation, storage, information, and selling. They also discuss differentiated goods. Differentiation can arise from many sources such as quality, culture, economies of scale, etc. We have emphasized some of these attributes in our work on grains.

One measure of intra-industry trade used by Grubel and Lloyd is:

$$1 - \frac{X - M}{X + M},$$

where X is exports and M is imports. This measure can range from zero—specialization in either exports or imports, to one—equality of X and M. We have calculated this index for wheat trade for the EC and the USSR for three five-year periods and for the isolated year 1974. The results are as follows:

	EC	USSR
1959–64	.80	.58
1964–69	.87	1.00

1969–74	.95	.98
1974	.85	.84

The other major nations in the world's wheat economy have indices of zero. Canada, United States, and Australia specialize in exports, and Japan specializes in imports. For what is generally perceived to be a homogeneous good, tobacco, the index for the United States in the mid-1970s was .66.

Richardson (1978) has presented perhaps the most sophisticated econometric analysis of differential prices in the spirit of testing the law of one price. He examines U.S. and Canadian price data disaggregated to the 4-digit standard international trade classification (SITC) level. He then is able to distinguish three broad groupings of commodities, "commodity arbitrage apparently present," "commodity arbitrage possibly present," and "no significant evidence of commodity arbitrage" (all quotes, p. 385). More interestingly, perhaps, he rejects perfect commodity arbitrage in every case. This finding leads him to conclude that every country's products can be considered as differentiated from every other country's.

Kravis and Lipsey, in a lengthy investigation of price differences in international trade, find evidence of differences in both levels and movements of prices for quite disaggregated commodity definitions. The bibliography is extensive. See the most recent work (Kravis and Lipsey) and the references there cited. Their empirical work is largely confined to manufactures. One of their major explanations for the observed price discrepancies is market imperfections. However, if, as we suspect, price discrepancies carry over almost entirely to agricultural products also, then the following statement from them makes even more sense. "One could go even further and define products or commodities in such a way that any price difference between two items means that they are different goods." (Kravis and Lipsey, p. 203.) They go on to say that this would make the law of one price prevail by assumption.

Both Kravis and Lipsey and Richardson thus conclude that prices differ among countries at the most disaggregated levels. The inferences are not as contradictory as they appear. Richardson takes his results as evidence of the failure of "perfect commodity arbitrage" (p. 385), while Kravis and Lipsey say that the law of one price would hold by assumption. The difference is mainly semantic. We doubt that there are a large number of unexploited arbitrage opportunities available in the trading world. The problem would seem to be one of identifying products, not of market failure. The problem is the ubiquitous one of finding real world counterparts to our theoretical constructs.

Models That Incorporate Differentiated Products

Our wheat trade model draws heavily on the theoretical model developed by Armington in a series of articles in the IMF Staff Papers (Armington 1969a, b; 1970a, b; 1973). As pointed out, Armington specifically assumes that consumers in third countries identify the origin of different goods coming into that country. Our variant of this basic model is outlined below. Meanwhile it should be useful to mention implementation of similar models.

Branson adopts the Armington model and utilizes it to examine the trade effects of the 1971 currency realignments. The empirical part of this exercise is at the highest level of aggregation—all trade.

Truman and Resnick also adopt a model that uses imperfect substitution among products. They investigated the effect of alternative tariff structures on West European trade flows. They also were dealing with nonagricultural products. Their model uses a two-stage procedure. In the first stage, imports and home production are differentiated to determine total imports into a country. In the second stage, imports from various sources are differentiated, and imports allocated on the basis of relative prices among alternative suppliers.

Two unpublished studies of agricultural products using the differentiated goods point of view are Wells and Collins. The first is an attempt to predict flows and prices of wheat imports to the United Kingdom upon entry into the EC. The latter is a world trade in coarse grains model.

The World Wheat Trade Model

In several studies (Johnson, Grennes, Thursby; Grennes, Johnson, Thursby 1978a, b; Thursby, Johnson, Grennes) we have applied the Armington-type model to the pre-

diction of multilateral trade flows and prices of grains. We do not specify whether it is product differentiation, transaction costs, or aggregation problems which make a spatial equilibrium model overly restrictive, since any of these are sufficient to cause the price of a single commodity in a single import market to vary by supplier. While the model, per se, is not original to us, our application of this type of model to predicting trade flows of primary commodities is original. This type of model generally has been thought to be inappropriate for this type of commodity classification; however, we have shown elsewhere (Thursby, Johnson, Grennes) that the model is both theoretically plausible and consistent with observed data.

Consider a world of n endogenous countries and m goods. Each of the m goods is potentially produced and consumed in all n countries. Because consumer prices of each good produced by different countries may differ in a single market, there are potentially mn^2 consumer prices to be predicted. Thus, demand in country k for good i produced by country j is potentially a function of country k's total expenditure and all consumer prices in country k. Using Armington's definitions, we call good i produced in country j a product. Thus a product demand function is represented as

$$(1)\quad Q_{ij}{}^k = f[E^k, P_{11}{}^k, \ldots, P_{1n}{}^k, \ldots, P_{ml}{}^k, \ldots, P_{mn}{}^k],$$

where i is $1, \ldots, m$; j, k is $1, \ldots, n$; E^k is country k's total expenditure (in country k's currency); $Q_{ij}{}^k$ is quantity demanded in country k of good i produced by country j; and $P_{ij}{}^k$ is consumer prices in country k of good i from country j (in country k's currency). Estimation of the demand equations for such a model would require estimation of $mn^2 + m^2n^3$ elasticities. Of these, mn^2 are expenditure elasticities, mn^2 are direct price elasticities, and $mn^2(mn - 1)$ are cross-price elasticities.

To reduce the number of parameters, the Armington-type model (1) assumes that (a) the marginal rate of substitution between any two kinds of a good is independent of any other goods in the importer's market basket, (b) the elasticity of substitution between any two kinds of a good in a given market is constant and equals the elasticity of substitution between any other kinds of the good in the same market. As Armington has shown (1969a), these assumptions imply product import demand functions given by

$$(2)\quad Q_{ij}{}^k = b_{ij}{}^{\sigma_{ki}}\, Q_i{}^k \left(\frac{P_{ij}{}^k}{P_i{}^k}\right)^{\sigma_{ki}},$$

where $Q_i{}^k$ is quantity consumed of good i in country k, b_{ij} is constant, σ_{ki} is elasticity of substitution in country k between types of good i (products of kind i), and $P_i{}^k$ is price index for good i in country k (country k's currency).

The way in which this demand function simplifies the problem can be seen more easily by rewriting (2) in terms of percentage changes. That is, for $Q_{ij}{}^k$ given by (2) the percentage change in demand can be expressed as

$$(3)\quad dQ_{ij}{}^k/Q_{ij}{}^k = \epsilon_{ki}dE^k/E^k + \eta_{ijj}{}^k dP_{ij}{}^k/P_{ij}{}^k + \sum_{h\neq j} \eta_{ijh}{}^k dP_{ih}{}^k/P_{ih}{}^k + \sum_{g=1}^{m} \eta_{ig}{}^k dP_g{}^k/P_g{}^k,$$

where ϵ_{ki} is expenditure elasticity for good i in country k, $\eta_{ijh}{}^k$ is price elasticity of demand in country k for good i produced by country j with respect to the price of good i produced by h, and $\eta_{ig}{}^k$ is price elasticity of demand in country k for good i with respect to the price of good g in country k. This demand structure reduces the number of demand elasticities to mn expenditure elasticities, mn^2 direct price elasticities, and $mn^2(n - 1)$ cross price elasticities for products of the same kind (i.e., $\eta_{ijh}{}^k$) and $mn(m - 1)$ cross price elasticities with respect to other goods' prices (i.e., $\eta_{ig}{}^k$).

Moreover, the mn^3 elasticities with respect to product prices of the same kind can be calculated from $2mn$ elasticity estimates and market share data [Armington, Hanoch]; that is,

$$(4)\quad \eta_{ijj}{}^k = (S_{ij}{}^k - 1)\sigma_{ki} - S_{ij}{}^k\eta_{ii}{}^k, \text{ and}$$

$$(5)\quad \eta_{ijh}{}^k = S_{ih}{}^k(\sigma_{ki} - \eta_{ii}{}^k) \text{ for } i \neq j,$$

where $S_{ij}{}^k = P_{ij}{}^k Q_{ij}{}^k / P_i{}^k Q_i{}^k$.

The rest of the model is straightforward. For short-run forecasting, we consider the supply side to be exogenous so that the mn supply equations (G_{ij}) are market clearing conditions:

$$(6)\quad G_{ij} = \sum_k Q_{ij}{}^k, \text{ or,}$$

in percentage change terms,

$$(7)\quad dG_{ij}/G_{ij} = \sum_k W_{ij}{}^k dQ_{ij}{}^k/Q_{ij}{}^k,$$

where

$$W_{ij}{}^k = Q_{ij}{}^k/G_{ij} \text{ and } \sum_k W_{ij}{}^k = 1.$$

Price equations are given by

$$(8) \qquad P_{ij}^k = r_{kj}P_{ij}^s + t_{ij}^k, \text{ or}$$

$$(9) \quad dP_{ij}^k/P_{ij}^k = (P_{ij}^s/P_{ij}^k)dr_{kj} + (r_{kj}/P_{ij}^k)dP_{ij}^s + dt_{ij}^k/P_{ij}^k,$$

where P_{ij}^s is supply price of good i produced by country j in country j's currency, r_{kj} is exchange rate between k and j, and t_{ij}^k are exogenous shifters that affect the difference between the origin price and ultimate consumer prices. Equations (2), (6), and (8) [or (3), (7), and (9)] give $2mn^2 + mn$ equations which yield mn^2 trade flows, mn^2 consumer prices, and mn supply prices.

There are two reasons this kind of model has not been used to predict trade flows of primary commodities. First, it was thought that since they are more homogeneous than many manufactured goods, the introduction of as many prices as there are trade flows was unnecessary. Second, the homogeneity of a disaggregated commodity classification has been thought inappropriate with the demand structure of the Armington-type model.

The latter objection concerns the constant elasticity of substitution assumption behind equations (2) and (3). It is that assumption which causes the cross-price elasticities in (5) to be invariant with respect to the product demanded. Moreover, expenditure elasticities are restricted so that products of a kind are either (*a*) normal with respect to good expenditure (E_i^k) and substitutes for each other, (*b*) all products of a kind but one being inferior and complements, with one being normal and a substitute for the rest, or (*c*) all products of a kind must be neutral and unrelated (Thursby, Johnson, Grennes; Silberberg 1972). The constant elasticity of substitution assumption further restricts the expenditure elasticities with respect to good expenditure, ϵ_{ij}^k, to be equal to unity. Thus, all products of the same kind are restricted to be substitutes. In terms of (3), this implies that if prices do not change, product import demand changes by the change in the importer's total expenditure on good i weighted by the share of the product in the importer's total expenditure on that good. While expenditure elasticities with respect to total expenditure on the good is restricted, no restriction is placed on expenditure or income elasticities for products.

These elasticity features have discouraged usage of this demand structure for disaggregated commodity groups since it is generally thought that the expenditure and cross-price elasticity restrictions are less likely to be violated by broadly aggregated commodity groups than by highly disaggregated commodities. That is, aggregates such as food, chemicals, and manufactures are likely to be neutral and unrelated, whereas products within one of those aggregates are likely to be complements and substitutes, with some being unrelated. Deaton takes exception to this view, asserting that implied restrictions of additivity on direct price elasticities are no more likely to hold for broad aggregates than for disaggregated commodity groups.

For estimation of demand functions, in general, this may be the case (Thursby, Johnson, Grennes), but there is no reason that this should be so for the demand side of trade flow models because of the way in which products and goods are defined in trade flow models. That is, where products are defined by country of origin, cross substitution elasticities among products of a kind refer not to substitution of one type of commodity for another, but to substitution of a good produced by one country for the same good produced by another country. In the case of trade flow models the unitary ϵ_{ij}^k and substitution requirement may be more intuitively appealing for models of elementary commodities than for models of aggregate commodity trade. That is, for models containing own consumption as a flow, it is not unlikely that for some countries, imports of manufactures and domestic manufactures could be complements. Different "kinds" of a primary commodity, however, are generally thought to be perfect or near-perfect substitutes. In the former case, a spatial equilibrium model is appropriate, but where differentiation is made among suppliers demand equations given by (2) [or (3)] have some appeal.

Applications of the Model

The model can be applied to a wide variety of problems. Earlier we analyzed the effect of dollar devaluation on wheat prices and wheat trade. The current world monetary system of managed floating which has produced large changes in exchange rates makes the question even more interesting than in the past. How have the recent depreciation of the U.S. and Canadian dollars and appreciation of the Japanese yen, German mark, and Australian dollar affected the world wheat market? To

the extent that the EEC has insulated itself from the impact of currency changes through the variable levy and border taxes, how has this policy increased the necessary adjustment of prices and quantities in other countries?

Just as dollar devaluation tends to increase the price of wheat in the United States, so does a decline in the cost of transporting exported wheat. Ocean freight rates have been set by shipping conferences which have attempted to act as a cartel. Recent erosion of the power of the international airline cartel along with the recent discovery of the virtue of competition by the Civil Aeronautics Board, stimulates interest in ocean freight rates. The effect of lower rates induced by competition can be analyzed by our model.

Inventories are a traditional device for reducing price variability, and the effect of inventory behavior during the volatile 1973–74 period has been analyzed. Current discussions of a new international wheat agreement assign a prominent role to inventories, and the price effects of alternative levels of inventories can be analyzed. Alternatively, one can determine what level of inventories would be necessary to achieve a target price under a given set of circumstances. One of the important circumstances is the prevailing set of trade controls, whose level can be varied to measure its impact on prices and required inventories. Earlier wheat agreements have attempted to keep prices within a specified range by assigning quotas to exporting countries, and the model can be used to calculate the requisite quotas. Finally, a current U.S. policy goal is greater access to the EEC market, and the effect of alternative levels of the EEC target price and the resulting levy can be analyzed.

Extensions of the Model

Some countries have attempted to stabilize domestic wheat prices by varying trade controls to offset changes in foreign prices. These insulating trade policies are sometimes automatic, as in the case of the EEC variable levy, or sometimes discretionary. Whether they are automatic or discretionary, systematic trade policies can be incorporated into the model as endogenous variables. Thus, a study of actual trade policies might permit the construction of a more general trade model. Since insulating policies separate domestic prices from foreign prices, they reduce the domestic response to foreign price changes and they make the observed price elasticities smaller than they would otherwise be. We have shown the effects of these trade policies on the world wheat market for 1973–74 (Grennes, Johnson, Thursby, 1978b), and we have done additional work on measuring the degree of insulation of domestic prices across countries. It appears that in the case of wheat, the EEC engages in the most insulation and the United States the least, but there are several alternative indices of insulation which could be employed. For example, one could use a measure of the variability of domestic prices across countries, the change in the level of effective protection, or a price transmission elasticity which measures the responsiveness of domestic prices to a given change in foreign prices (Abbott).

Another extension of the wheat model is to relate it to the effect of aggregation on the pattern of world trade. We discussed earlier the evidence that has been accumulated in the empirical testing of the "Law of One Price." These tests have implications for the monetary approach to the balance of payments and the purchasing power parity theory. It is generally agreed that one of the reasons for the poor performance of the law in empirical studies is the high level of aggregation of the trade data. However, some authors feel that the law would hold at the level of aggregation of wheat (Isard, p. 942, Black, p. 36). Since we have found wheat to be usefully treated as a differentiated product, we are inclined to believe that few goods would obey the law. We intend to pursue this point with other commodities and countries.

References

Abbott, Philip. "Modelling International Grain Trade with Government Controlled Markets." Mimeographed. Boston, Boston College, 1978.

Armington, Paul S. "A Theory of Demand for Products Distinguished by Place of Production." *IMF Staff Papers* 16(March 1969):159–78.

———. "The Geographic Pattern of Trade and the Effects of Price Change." *IMF Staff Papers* 16(July 1969):179–99.

———. "A Many Country Model of Equilibrating Adjustments in Prices and Spending." *IMF Staff Papers* 17(March 1970):23–26.

———. "Adjustment of Trade Balances: Some Experiments with a Model of Trade Among Many Countries." *IMF Staff Papers* 17(November 1970):488–517.

———. "A Note on Income-Compensated Price Elas-

ticities of Demand Used in the Multilateral Exchange Rate Model." *IMF Staff Papers* 20(November 1973):608–11.

Black, Stanley. *Floating Exchange Rates and National Economic Policy*. New Haven, Conn.: Yale University Press, 1977.

Branson, William. "The Trade Effects of the 1971 Currency Realignments." *Brookings Papers on Economic Activity* 1(1972):15–67.

Collins, Keith. "An Economic Analysis of Export Competition in the World Coarse Grain Market: A Short-Run Constant Elasticity of Substitution Approach." Ph.D. thesis, North Carolina State University, 1977.

Deaton, Angus. "A Reconsideration of the Empirical Implications of Additive Preferences." *Econ. J.* 84(1974):338–48.

Grennes, T. J., P. R. Johnson, and Marie Thursby. *The Economics of World Grain Trade*. New York: Praeger Publishers, 1978.

———. "Insulating Trade Policies, Inventories, and Wheat Price Stability." *Amer. J. Agr. Econ.* 60(1978):132–34.

Grubel, Herbert, and P. J. Lloyd. *Intra-Industry Trade: The Theory and Measurement of International Trade in Differentiated Products*. New York: John Wiley & Sons, 1975.

Hanoch, Giora. "Production and Demand Models with Direct and Indirect Implicit Additivity." *Econometrica* 43(1975):395–419.

Harberger, Arnold. "Some Evidence on the International Price Mechanism." *J. Polit. Econ.* 65(1957):506–21.

Isard, Peter. "How Far Can We Push the Law of One Price?" *Amer. Econ. Rev.* 67(1977):942–48.

Johnson, H. G. *Comparative Cost and Commercial Policy Theory for a Developing World*. Stockholm, Sweden: Almquist and Wicksell, 1968.

Johnson, Paul R. "Studies in the Demand for U.S. Exports of Agricultural Commodities." Department of Economics Econ. Res. Rep. No. *15*, North Carolina State University, 1971.

Johnson, Paul R., T. J. Grennes, and Marie Thursby. "Devaluation, Foreign Trade Controls, and Domestic Wheat Prices." *Amer. J. Agr. Econ.* 59(1977):619–27.

Kravis, Irving, and Robert Lipsey. "Price Behavior in the Light of Balance of Payments Theories." *J. Int. Econ.* 8(1978).

Lancaster, Kelvin. "A New Approach to Consumer Theory." *J. Polit. Econ.* 74(1966):132–57.

Magee, Stephen. "Prices, Incomes and Foreign Trade." *International Trade and Finance*, Peter Kenen. Cambridge: Cambridge University Press, 1975.

Nelson, Phillip. "Information and Consumer Behavior." *J. Polit. Econ.* 78(1970):311–29.

———. "Advertising as Information." *J. Polit. Econ.* 82(1974):729–54.

Orcutt, Guy. "Measurement of Price Elasticities in International Trade." *Rev. Econ. and Statist.* 32(1950):117–32.

Richardson, J. David. "Beyond (but back to?) the Elasticity of Substitution." *Europ. Econ. Rev.* 4(1973):381–92.

———. "Some Empirical Evidence on Commodity Arbitrage and the Law of One Price." *J. Int. Econ.* 8(May 1978):341–52.

Schmalensee, Richard. "A Model of Advertising and Product Quality." *J. Polit. Econ.* 86(1978):485–503.

Silberberg, Eugene. "Separability and Complementarity." *Amer. Econ. Rev.* 62(March 1972):196–97.

Stigler, George. "The Economics of Information." *J. Polit. Econ.* 69(1961):213–25.

Telser, Lester. "The Demand for Branded Goods as Estimated from Consumer Panel Data." *Rev. Econ. and Statist.* 44(1962):300–24.

———. "Searching for the Lowest Price." *Amer. Econ. Rev.* 63(May 1973):40–49.

Thursby, Marie, P. R. Johnson, and T. J. Grennes. "A Disaggregated World Trade Flow Model." Unpublished paper, Department of Economics, North Carolina State University, 1978.

Truman, Edwin, and Stephen Resnick. "An Empirical Examination of Bilateral Trade in Western Europe." *J. Int. Econ.* 3(Nov. 1973):305–35.

Turnovsky, Stephen. "International Trading Relationships for a Small Country: The Case of New Zealand." *Can. J. Econ.* 1(1968):772–90.

Wells, Gary. "The Impact on Wheat Import Patterns from the Entrance of the United Kingdom into the European Economic Community." Ph.D. thesis, Department of Economics and Business, North Carolina State University, 1977.

Quantitative Evaluation of Stabilization Policies in International Commodity Markets

David Blandford and Seon Lee

In recent years there has been heightened interest in the stabilization of international commodity markets. The "commodity boom" of 1972–75, and the rapid rise in grain prices in 1973–74 generated political pressures in both developed and less developed countries (LDCs) for commodity market control. The 1974 World Food Conference in Rome had as one of its themes the establishment and management of international reserve stocks to stabilize grain markets and provide food security. The 1976 meetings of the United Nations Conference on Trade and Development (UNCTAD) in Nairobi were dominated by a proposal to introduce an integrated program for commodities (IPC). This program has as its central point the creation of an extensive series of international commodity agreements to act as market stabilizers.

Such developments have stimulated the interest of economists, who have sought to examine the issues raised from both theoretical and empirical perspectives. The purpose of this paper is to discuss briefly the major approaches that have been adopted in the empirical analysis of stabilization policy, to identify their advantages and disadvantages, and to indicate some important analytical questions that arise in the modeling of instability. The primary focus is on agricultural commodities, but methods and problems discussed are not confined to these alone.

Empirical Application of Stabilization Theory

Economists have been interested in the impact and desirability of commodity market stabilization for some time. Although the implications of stabilizing income and consumption or production have received limited attention, the major focus has been on price stabilization (Turnovsky). Much of the analysis has been carried out in a comparative static, partial equilibrium framework utilizing the concept of economic surplus. In an important contribution to the literature, Massell employs linear supply and demand curves with additive stochastic disturbances, to assess the impact of price stabilization at the mean through a costless buffer stock. He demonstrates that whether producers or consumers gain depends on the source of random fluctuation. However, costless stabilization will always produce a potential Pareto improvement in aggregate (consumer plus producer) welfare. Subsequent extensions to the Massell approach have sought to examine the effect of alternative assumptions on these results. Major modifications have included the introduction of response lags and multiplicative disturbances. Although Massell's overall conclusion continues to hold, the distribution of gains between participants is sensitive to such assumptions (Turnovsky).

Massell's formulas for gains and losses have been used empirically by McNicol to estimate expected annual gains from buffer stock price stabilization for the ten "core" commodities in the IPC (cocoa, coffee, copper, cotton, jute, rubber, sisal, sugar, tea, and tin. Seven other commodities are included in the program, viz., bananas, bauxite, beef and veal, iron ore, rice, wheat, and wool). Econometric estimates of supply/demand elasticities and a simple probability distribution are applied to 1971 average price and production to compute expected gains/losses under various assumptions about the origins of instability. Konandreas and Schmitz, building upon an extension of the Massell model, use somewhat more sophisticated econometric modeling to ana-

David Blandford is an assistant professor and Seon Lee is a graduate student in the Department of Agricultural Economics, Cornell University.

lyze the effects of grain price stabilization on the welfare of U.S. producers and consumers.

Another part of the theoretical literature has concentrated on the impact of price stabilization on the income or export earnings of producers (Grubel). In an empirical context, Brown employs a two-period comparative static analysis to examine the effects of buffer funds, buffer stocks, and export quotas on the export earnings of cocoa producers. Using a somewhat different approach Brook, Grilli, and Waelbroeck attempt to assess the probable impact of price stabilization on producer earnings from seventeen primary commodities. Drawing upon Grubel's analysis, they argue that a positive relationship between deviations from historical trend indicates that demand shifts are the major cause of instability, and that price stabilization would therefore reduce earnings. The opposite relationship is taken to signify that supply shifts dominate, and, hence, stabilization would increase earnings.

One of the major advantages of theoretical analysis is that within a given set of assumptions, a definitive answer to the question of the impact of stabilization can be derived. However, there is necessarily a high price incurred in terms of the level of abstraction that must be made from the complexity of the "real world." Comparative static equilibrium analysis has a role to play in suggesting factors or issues that may prove important (Just), but from the perspective of providing a framework for direct empirical application it clearly has severe limitations. Indeed, important questions tend to be overlooked by this mode of analysis. An overwhelming concentration on the single objective of price stabilization, and the general assumption that the policy maker (buffer stock manager for example) behaves "optimally" to stabilize price at the mean, prove limiting. Furthermore, the temporal effects of actual or proposed policies, possibly involving multiple objectives and subject to operational costs and constraints, are frequently of greater interest than a result which may hold asymptotically.

For these reasons, many analysts have concentrated on the development and use of more realistic market analogues, through which the temporal effects of various stabilization policies on prices, incomes, or economic surplus can be determined. In some cases analysis has taken the form of *ex post* evaluation, that is with reference to a particular historical period (frequently the period used to estimate an econometric model), in others it has been *ex ante*, where the model has been used in a forecasting mode. The most popular method adopted has been simulation.

Simulation Analysis of Stabilization Policy

A basic component of simulation analysis for stabilization policy is a rule, or rules, for market intervention. The most widely used are storage rules to determine the operation of a commodity reserve or buffer stock. They can be divided into quantity rules and price rules.

The former specifies the quantity stored as a function of production, supply, or a target quantity; for example,

$$(1) \qquad x_t = q_t - q^*_t,$$

where x is the change in the level of stocks held, q is actual production, and q^* is target or desired production. If production exceeds q^*, or some specified upper bound, then the difference is stored. If production falls below q^*, or some specified lower bound, then the difference is released from storage (e.g., Reutlinger). The rule may be modified by storage capacity/stock availability or other constraints. The use of quantity rules has been primarily confined to the analysis of grain reserves.

Price rules generally specify storage activity as a function of target or desired price; for example,

$$(2) \qquad x_t = k(p_t - p^*_t),$$

where p is the "free market" price, p^* is a desired price, and k represents a function which relates storage activity to the price difference. If free market price exceeds p^*, or some specified upper bound, the product is sold by the storage agency. If free market price falls below p^*, or some specified lower bound, stocks are accumulated (e.g., Behrman, Cochrane and Danin, UNCTAD).

Both deterministic and stochastic simulation techniques have been used to assess the impact of storage rules. In some cases simple nondynamic models have been the medium of analysis (e.g., Murray and Atkinson, Reutlinger). These have the advantage of relative analytical simplicity. They permit the evaluation of alternative decision rules and the effects of constraints, and can be used to examine the impact of alternative response param-

eters and types of disturbance. In stochastic applications, the probability of success in achieving alternative objectives under various scenarios can be inferred. However, since simple models are employed, this type of analysis tends to suffer from the same problems of realism that affect empirical applications of stabilization theory.

The most interesting use of simulation is in the context of dynamic market models which are typically derived econometrically. Although the characteristics of individual models can vary quite widely, they generally explain demand (consumption), supply (production or exports), and price formation or inventory behavior (Labys). Such models can be characterized as systems of first- or higher-order difference equations.

In a recent example of a deterministic application, Behrman assesses the possible costs and impact of buffer stock stabilization for thirteen commodities in the IPC. Stabilization around actual secular price trend, and an increasing secular trend, is evaluated over the period 1963–72. In a comparable UNCTAD study, stochastic simulation is employed to assess the costs of buffer stock operations for ten "core" commodities in the IPC. Randomness is introduced through additive error terms in estimated supply equations. Randomly generated disturbances are derived from a normal probability distribution with zero mean and standard deviation estimated from sample period residual errors. Three hundred replications, over a five-year forecast period (1979–83), are used to assess the probability of successful stabilization around alternative target prices with various levels of financial resources.

Simulation is a flexible approach which, particularly in the context of dynamic models, can provide useful insights for stabilization policy. It proves most useful for the analysis of single objectives such as the stabilization of price around trend. One of its major limitations, however, is the difficulty of identifying "optimal" policy, that is, the decision rule which achieves a given set of objectives most efficiently. Behavioral rules are usually imposed in an ad hoc way, and it is difficult or extremely tedious to determine the most appropriate. Analytical approaches based upon mathematical optimization remedy this difficulty.

Optimization Analysis of Stabilization Policy

An alternative, although less widely employed, approach is mathematical optimization. In this approach policy aims are specified formally in an objective function, market behavior and other constraints define the feasible region, and "optimal" policy actions are determined by constrained optimization. A simple example is illustrative:

(3) $$D = \alpha - \beta p \qquad \text{Demand},$$

(4) $$S = \gamma + \delta p + e + x \qquad \text{Supply},$$

(5) $$S = D \qquad \text{Market Clearing},$$

where e is an additive disturbance term of known value, and x is the net change in stocks held by a storage agency. Assume for simplicity that storage is costless and that the policy objective is to maximize an index of social benefit defined by consumers' surplus,

(6) $$\text{Max } W = \int_{\alpha/\beta}^{p} (\alpha - \beta p)dp.$$

Evaluation of the integral, substitution for equilibrium price from (3)–(5), and differentiation with respect to x yields

(7) $$x = \frac{\alpha}{\beta(\beta + \delta)} + (\gamma + e - \alpha).$$

This is the quantity rule for storage activity which maximizes the policy objective function. It implies that *ceteris paribus*, such activity is a decreasing function of the slope of the demand (or supply) curve.

Alternatively, the policy objective might be to minimize the difference between market price and a desired price (p^*). This could be expressed by an objective function of the form

(8) $$\text{Min V} = (p - p^*)^2.$$

Substitution for equilibrium price, and differentiation with respect to x yields

(9) $$x = -(\beta + \delta) \quad (p - p^*).$$

This is the price rule for storage activity to minimize the objective function. It implies that if p is greater than p^*, sales from existing stocks are required; whereas, if p is less than p^*, purchases are required. It is interesting to note that in this case stocking activity is *ceteris paribus* an increasing function of the slope of the demand (or supply) curve.

These simple examples illustrate some important issues in the empirical analysis of

stabilization policy. The nature of policy objectives is of fundamental importance in determining appropriate market-intervention behavior. If such objectives can be specified in a mathematically tractable way, then optimization provides an attractive framework for deriving and assessing the impact of decision rules. From a slightly different perspective, ad hoc decision rules of the type frequently employed in simulation analyses may imply strong, undefined assumptions about stabilization objectives. Even if "ad hocery" more closely reflects the character of most centralized intervention in commodity markets, it seems useful to have some means of determining how near the results are to "optimal" behavior.

Although optimization, like simulation, has been employed in the context of static models (e.g., Johnson and Sumner), its greatest potential lies in the application of optimal control theory to the stabilization of dynamic commodity markets. For example, let us assume that the appropriate econometric model is linear and that the following reduced-form can be derived:

$$(10)\quad \mathbf{y}_t = A_1\mathbf{y}_{t-1} + \ldots A_n\mathbf{y}_{t-n} + B_O\mathbf{x}_t + \ldots + B_m\mathbf{x}_{t-m} + \mathbf{b}_t + \mathbf{e}_t,$$

where $\mathbf{y}_t$ is a vector of endogenous variables, $\mathbf{x}_t$ is a vector of control (policy) variables, $\mathbf{b}_t$ is a vector of exogenous variables not subject to control, $\mathbf{e}_t$ is a vector of random disturbances, and the elements of the matrices $A_1, \ldots, A_n$, $B_O, \ldots, B_m$ are known constants. Through the use of appropriate identities the system can be simplified to

$$(11)\quad \mathbf{y}_t = A\mathbf{y}_{t-1} + B\mathbf{x}_t + \mathbf{b}_t + \mathbf{e}_t,$$

where the vector $\mathbf{y}_t$ is redefined to include current and lagged dependent variables, as well as current and lagged control variables.

If we define an objective or "welfare" function of the general form

$$(12)\quad W = f(\mathbf{y}_t, \mathbf{x}_t, \mathbf{e}_t),$$

then the problem is one of maximizing or minimizing the function (12) over T time periods, subject to the constraints imposed by the market system (11). This is achieved by the selection of an optimal set of control variables which are determined from the equations

$$(13)\quad \mathbf{x}_t = G_t\mathbf{y}_{t-1} + \mathbf{g}_t,$$

where G is the feedback gain matrix and $\mathbf{g}$ is a vector of tracking elements. Their exact form and derivation through the methods of Lagrange multipliers and dynamic programming are contained in Chow. In the context of stock management, where x would represent purchases or sales by a storage agency in each period, equation (13) defines the storage rule to maximize or minimize the criterion function over the planning horizon.

The extension of the price variability minimization problem (8) to a control framework would imply a loss function of the form

$$(14)\quad \text{Min } E(W) = \sum_{t=1}^{T}(p_t - p^*_t)^2.$$

Following Chow, this can be decomposed into deterministic and stochastic components

$$(15)\quad \text{Min } E(W) = \sum_{t=1}^{T}(\bar{p}_t - p^*_t)^2 + E\sum_{t=1}^{T}(p_t - \bar{p}_t)^2,$$

where $\bar{p}$ is a price determined solely by systematic forces in the market system. The storage rule derived from (13) is

$$(16)\quad \mathbf{x}_t = -\phi(p_t - p_t^*),$$

where ϕ is the sum of response coefficients on current price included in (11).

Although (16) bears some similarity to the type of ad hoc price rule (2) employed in simulation analysis, it is important to note that its deviation through control theory implies that storage behavior will minimize price deviations from desired values over the multiperiod planning horizon.

Equation (15) highlights the importance of systematic versus stochastic variability in the implementation of stabilization policy. In deterministic control applications only the former is considered. For example, Dalton uses a deterministic approach to analyze stocking policy for wool. He argues that this is appropriate because the major cause of price fluctuation is the variability of systematic economic factors.

In dealing with stochastic fluctuations, some authors have adopted the related certainty equivalence concept (e.g., Kim, Goreux, and Kendrick), in which appropriate policy is derived *ex ante* by setting random variables equal to their expected value of zero. One difficulty with this approach is that it effec-

tively de-emphasizes stochastic disturbance, when frequently this is the most important source of variation in commodity markets. In fact, centralized storage activity is often intended solely to offset its effect. Hence, the greatest potential for control theory would seem to be as a method for evaluating the effects of alternative stabilization objectives, instruments, and decision rules in the presence of system disturbances. Its employment in an *ex post* or *ex ante* simulation mode would seem to be most promising. Previous studies (e.g., Kim, Goreux, and Kendrick) suggest the potential which exists for assessing tradeoff between multiple objectives within this type of framework.

The simple quadratic/linear specification illustrated by (14) and (11) above can prove useful in some cases; however, solution methods have been developed for other types of problem, for example one involving nonlinear constraints (Chow). Furthermore, considerable potential may exist for the incorporation of uncertainty about the parameters of the system, and decision-maker learning through adaptive control (Rausser and Freebairn).

Some Problems in Modeling Instability

One of the fundamental requirements for empirical analysis of stabilization policy is that the model employed should reflect adequately the nature, source, and transmission of instability in the market system. Commodity models generally incorporate two sources of fluctuation: systematic and nonsystematic factors. Changes in variables which are assumed to be exogenous, such as population, incomes, and technology, create systematic fluctuations in endogenous variables such as price. Nonsystematic factors, which are indeterminate or difficult to specify explicitly such as weather, also create fluctuations in endogenous variables. The influence of such factors is usually relegated to residual error terms, but may also be reflected through dummy variables. In a simultaneous system, the effect of a residual disturbance which is attributed to one endogenous variable will be transmitted to other endogenous variables during a single time period.

The impact of changes in systematic factors on system variability can be analyzed either by assuming a specific set of values for an exogenous variable, or by generating these randomly from a density function. To some extent fluctuations in these variables are predictable and are frequently identified as "acceptable" market instability. Solution of the model, with observed or forecast values of such variables and stochastic disturbances suppressed, can be used to provide target values for simulation or control analysis. These may prove to be more appropriate than the rather crude moving average, or secular trend alternatives, which are frequently adopted (e.g., Behrman, Kim et al., UNCTAD). For example, in the case of (15) a neutral storage policy, having no effect upon systematic price changes, would be defined with the vector $\bar{p}$ as target prices.

In much empirical analysis of stabilization policy, major attention has been focused on instability derived from nonsystematic factors, assumed to be reflected in residual error terms. This is because stabilization devices such as buffer or reserve stocks are mainly oriented toward the control of short-term fluctuations rather than long-run cyclical or secular changes. It is common practice, for example, to identify the unexplained variation in yield or production as a system disturbance attributable to weather, and to use this as a major input in the evaluation of stabilization policy.

Two alternative methods of using such disturbances exist. In the first, which we will call method A, the actual residuals from least squares regression are used to assess the impact of policy response over a particular period. This has its most obvious application to the *ex post* evaluation of alternative policies over the sample period. In the second method, which we shall call method B, regression residuals are used to specify a probability distribution for system disturbances. Both methods raise some interesting issues.

In employing method A, an assumption is presumably made that the series of estimated sample disturbances (u), is an acceptable representation of a corresponding series of true system disturbances (e). However, it should be recalled that one of the properties of least squares residuals is that even if the elements of e are serially independent, the elements of u are not (Theil, p. 196). Furthermore, even if the true residuals are homoscedastic the least squares residuals may be heteroscedastic. These residuals may not therefore have desirable properties, and we may doubt their ability to reflect a pattern of true system disturbance.

One possible remedy for this problem would be to use an appropriate estimator to derive estimates of true disturbances which would possess desirable properties, and use these in a method A-type application. For example, the use of the BLUS procedure (Theil) could be one way to derive a set of such disturbances, albeit at the cost of truncating the period of analysis. Whether the gain in terms of analytical "purity" would outweigh the added computational cost is perhaps open to debate.

Method B, the use of least squares residuals to define a probability distribution for the true stochastic disturbance, has proved extremely popular in the past. The most usual approach has been to employ the variance of the residuals as an estimator of the variance of the true disturbances, which are assumed to be normally distributed with zero mean and constant variance. An appropriate estimator of the true variance in the case of small samples would seem to be $u'u/(n - k)$ where n is the number of observations and k is the number of explanatory variables. When interdependency between system disturbances exists, more complex methods may be required to derive the appropriate probability distribution. Nagar, for example, discusses a method for obtaining estimates of a multivariate normal distribution for a simultaneous equation system with contemporaneously independent disturbances. Appropriate moments of a non-simultaneous system with contemporaneously correlated disturbances can be derived from Zellner's method of seemingly unrelated regressions, while three-stage least squares would be appropriate in the corresponding simultaneous case.

A number of important questions are raised by the use of sample disturbances to estimate a density function for true system disturbances. In the first place, to what extent is a constant variance assumption realistic? Many commodity models, particularly those which seek to explain the operation of international markets, use quantity-dependent supply functions. The variance of an underlying stochastic disturbance in yield may be constant, but with significant changes in acreage, the variance of disturbances in supply will certainly not be so. In this case, homoscedasticity is an unreasonable assumption which should affect both choice of estimation technique and the specification of a probability function for system disturbances.

A second issue is the implication of the use of dummy variables to account for "exceptional" weather conditions or other factors which create "outliers" in dependent variables. It is frequently necessary to adopt this technique because of the sensitivity of least squares estimators to extreme observations in small samples. But what if such weather conditions are part of the true weather variance? By their removal, the estimate of the true variance is truncated, and the relevance of an analysis based upon it is thereby limited. This would seem to present especially serious problems when the objective is to provide a probabilistic assessment of the success of a particular stabilization scheme. One way to deal with the outlier problem would be to produce adjusted least squares residuals by including the shift effect of dummy variables. These adjusted disturbances would then be used to estimate the variance. An alternative would be to incorporate specific explanatory variables to explain system disturbance due to such factors as weather, rather than relying upon the error term. In aggregate market models such an approach may prove difficult and expensive.

A further issue of some importance is the validity of the assumption of normality. It should be recalled that this is not needed for least squares to yield best linear unbiased estimators of structural parameters; however, it is required to perform conventional significance tests. In the case of stabilization analysis considerable importance is attached to the disturbances per se, and it therefore seems appropriate to pay greater attention to their actual distribution than would usually be the case. A priori, the normality assumption might seem perfectly appropriate for a disturbance which is specifically attributed to the influence of weather. In other cases, however, the situation is much less clear. In some studies, for example, disturbances in demand equations have been equated with the impact of unspecified policy changes. It is not immediately obvious that these should be normally distributed nor indeed serially independent. A case could therefore be made for more careful analysis of error terms than has been typical hitherto. Anscombe indicates a number of methods that can be used to examine the characteristics of estimated residuals; Ramsey also discusses the problem.

Careful analysis of residuals may have the added advantage of permitting a fuller assess-

ment of the appropriateness of a particular model specification, especially in terms of whether additive or multiplicative disturbances seem to be more appropriate. This question has been identified by some analysts as crucial to the empirical evaluation of the effects of stabilization policy (Just).

Concluding Comments

Empirical modeling undoubtedly will continue to prove a major medium for the analysis of alternative stabilization policies in international commodity markets. In the past, simulation has proved the most popular technique, but optimal control theory seems to possess a number of distinct advantages. Most important is the way in which appropriate decision rules for market intervention are directly derived from underlying policy objectives, and the ability of the method to deal with multiple, and sometimes conflicting, aims.

Numerous problems arise in the specification, estimation, and use of commodity models, and there are many possible directions for future improvement (Just, Klein, Labys). Some of the most important, and neglected, methodological issues relate to the identification of systematic and stochastic disturbances in market systems. Appropriate decomposition and analysis of such disturbances is central to a meaningful empirical evaluation of stabilization policy.

References

Anscombe, F. J. "Examination of Residuals." *Fourth Berkeley Symposium on Math. Stats. and Prob.* 1(1961):1–36.

Behrman, J. R. *International Commodity Agreements: An Evaluation of the UNCTAD Integrated Commodity Programme.* Overseas Development Council Monograph No. 9. Washington, D.C., Oct. 1977.

Brook, E. M., E. R. Grilli, and J. Waelbroeck. *Commodity Price Stabilization and the Developing Countries: The Problem of Choice.* IBRD Staff Working Paper No. 262. July 1977.

Brown, C. P. "Short-Run Static Price and Income Effects of Cocoa Control." *J. Devel. Studs.* 6(1970):267–282.

Chow, G. C. *Analysis and Control of Dynamic Economic Systems.* N.Y.: John Wiley & Sons, 1975.

Cochrane, W. W., and Y. Danin. *Reserve Stock Grain Models, The World and the United States, 1975–85.* Agr. Exp. Sta. Tech. Bull. No. 305, University of Minnesota, 1976.

Dalton, M. E. "Dynamic Stockholding Policies for Stabilising the Wool Market." *Quart. Rev. Agr. Econ.* 29(1976):179–192.

Grubel, H. G. "Foreign Exchange Earnings and Price Stabilization Schemes." *Amer. Econ. Rev.* 54 (1964):378–385.

Johnson, D. G. and D. Sumner. "An Optimization Approach to Grain Reserves for Developing Countries." *Analysis of Grain Reserves, A Proceedings.* USDA ERS Report No. 634, August 1976.

Just, R. E. "Theoretical and Empirical Possibilities for Determining the Distribution of Welfare Gains from Stabilization." *Amer. J. Agr. Econ.* 59(1977):912–917.

Kim, H. K., L. M. Goreux, and D. A. Kendrick. "Feedback Control Rule for Cocoa Market Stabilization." Labys.

Klein, L. R. "Potentials of Econometrics for Commodity Stabilization Policy Analysis." *Stabilizing World Commodity Markets,* eds. F. G. Adams and S. A. Klein. Lexington, Mass.: Lexington Books, 1978.

Konandreas, P. A., and A. Schmitz. "Welfare Implications of Grain Price Stabilization: Some Empirical Evidence for the United States." *Amer. J. Agr. Econ.* 60(1978):74–84.

Labys, W. C., ed. *Quantitative Models of Commodity Markets.* Cambridge, Mass.: Ballinger Publishing Co., 1975.

Massell, B. F. "Price Stabilization and Welfare." *Quart. J. Econ.* 83(1969):284–98.

McNicol, D. L. *Commodity Agreements and Price Stabilization.* Lexington, Mass.: Lexington Books, 1978.

Murray, J. W., and L. J. Atkinson. *An Analysis of the UNCTAD Integrated Program for Commodities.* USDA ESCS For. Agr. Econ. Rep. No. 148, May 1978.

Nagar, A. L. "Stochastic Simulation of the Brookings Econometric Model." *The Brookings Model: Some Further Results,* ed. J. S. Duesenberry et al. Chicago: Rand-McNally & Co., 1969.

Ramsey, J. B. "Classical Model Selection through Specification Error Tests." *Frontiers in Econometrics,* ed. P. Zarembka. New York: Academic Press, 1974.

Rausser, G. C., and J. W. Freebairn. "Approximate Adaptive Control Solutions to U.S. Beef Trade Policy." *Ann. Econ. and Soc. Measure.* 3(1974):177–203.

Reutlinger, Shlomo. "A Simulation Model for Evaluating Worldwide Buffer Stocks of Wheat." *Amer. J. Agr. Econ.* 58(1976):1–12.

Theil, H. *Principles of Econometrics.* New York: John Wiley & Sons, 1971.

Turnovsky, S. J. "The Distribution of Welfare Gains from Price Stabilization: A Survey of Some Theoretical Issues." *Stabilizing World Commodity Markets,* ed. F. G. Adams and S. A. Klein. Lexington, Mass.: Lexington Books, 1978.

United Nations, Conference on Trade and Development. *Consideration of Issues Relating to the Establishment and Operation of a Common Fund.* TD/B/IPC/CF/L.2, 29 Dec. 1976.

The Role of Government Interference in International Commodity Trade Models

Philip C. Abbott

The fact that governments intervene in both domestic and international commodity markets is well recognized by market analysts and policy makers. Current GATT negotiations are addressing the consequences of such interventions for international trade, and the U.S. chief negotiator, Robert Strauss, reports that trade restrictions on agricultural commodities represent a particularly difficult stumbling block ("Chief U.S. Trade Negotiator at Geneva . . ."). The interest in international commodity agreements and market stabilization also indicates a concern for the behavior of these markets and particularly for the consequences of and potential for intervention in these markets.

The following categories and examples illustrate the types of devices through which governments influence international commodity trade:

(*a*) Standard protection devices—tariffs and quotas or variations on these are used to maintain high domestic prices and limit imports. The variable levy of the European Economic Community (EEC) and Japan's minimum import prices are important examples.

(*b*) Oligopolistic market control—commodity agreements, formation of cartels, nationalization or government control of an export industry, formation of government boards which make stockpiling and export decisions, or the use of export taxes and subsidies often have been used either to expand exports or to increase (or maintain) international prices. Examples of these include the International Wheat Agreement, Organization of Oil Exporting Countries (OPEC), the Canadian Wheat Board, and U.S. export subsidies on wheat.

(*c*) Intervention in domestic markets—price support programs, stockpiling, restrictions on resource use, or subsidization of investment are used to transfer income to commodity producers or maintain prices and production levels. Examples are the price support programs prevalent in many countries, the U.S. land bank in the 1960s, and investments since 1975 by the Brazilian government to restore coffee production in areas less subject to freezing.

It is not the intention of this paper to argue that such devices and the role of government have been ignored in models of commodity trade, as this has certainly not been the case. Analysts (e.g., Adelman) often invoke cartel arguments to explain the behavior of OPEC and increases in petroleum prices. In 1966, McCalla argued that the Canadian Wheat Board was acting as an oligopolistic price setter and the U.S. export subsidy on wheat was used to follow their lead. Alaouze, Watson, and Sturgess have recently presented a triopoly model of pricing in the world wheat market. The variable levies of the EEC have led to detailed analyses of their consequences by Berntson, Goolsby, and Nohre of U.S. Department of Agriculture (USDA). In the spatial equilibrium framework used to model international grain trade, as introduced by Bawden and utilized by USDA, specific constraints generally are included to capture the consequences of government interventions in those markets.

The problem with the above approaches and particularly their integration into commodity trade models is that the policy presumptions are subjected to econometric tests in few instances and levels of government intervention are treated as exogenous influences. Tariff and quota levels or other government interventions affecting international commodity markets are taken as exogenous parameters, rather than as variables which depend upon international market conditions. In the USDA's spatial equilibrium models of grain markets, either domestic and world prices are

---

Philip C. Abbott is an assistant professor in the Department of Economics, Northeastern University. Thanks are due to Lance Taylor and Gordon Rausser, with whom this author has discussed the ideas in this paper.

separated by a fixed, exogenous tariff or by exogenously fixing consumption and/or productions levels. This author (Abbott 1979) has argued elsewhere, however, that certain motivations, particularly domestic market outcomes which result in government behaviors responsive to world market conditions rather than fixed intervention levels, may be a better characterization of government policy. Internal price stability subject to partial adjustment to world market prices is put forward as one example of a government policy which is best modeled with the government included as a behavioral agent using tariffs, quotas, and internal price support programs as instruments to achieve policy objectives.

In this paper, two approaches to the endogenization of the role of government in models of international commodity trade are examined. These approaches range from a fully specified model, including government as a behavioral agent, to a means for interpretation of net import demand models in the light of my presumptions on the role of government. In each case, implications for econometric estimation and problems associated with integrating these models with the more standard spatial equilibrium approach will be addressed.[1]

Net Import Demand Models

One approach to the endogenization of government intervention into commodity trade models is the estimation and subsequent use in simulation of net import demand. That is, for a country and commodity, an equation of the following form,

(1) imports − exports = f [border (world) price, production, population, income, policy determining factors],

replaces estimation of trade flows as the residual which balances an estimated supply with an estimated demand. This author has shown elsewhere (Abbott 1977) that such an equation represents a reduced-form model of the latter approach, with policy-determining factors included as variables in the model. Parameter magnitudes, based on domestic supply and demand parameters and policy presumptions, can be determined a priori, and tests of hypotheses based on those presumptions may be conducted. If parameters relevant to the standard supply-demand approach are correct, this can be verified econometrically, in principal. If other influences matter, such as government policy, this will be reflected in parameters estimated for the net import demand model.

One advantage to the net import demand approach is that a straightforward estimation of trading behavior requiring only modest knowledge of an individual country's policies is allowed. The reduced form nature of such equations—the fact that what is estimated is simply the marginal effect of exogenous variables on trade—insures that price effects and the influences of other variables include the influence of government policy. With a somewhat better understanding of domestic policies and with estimates of domestic supply and demand parameters, hypothesis tests on the role of government also may be conducted. This author's earlier work presents a simplified example of such tests. In addition, the reduced-form nature of the model allows estimation of equations using ordinary least squares regression, so determination of appropriate instruments is not required when a country's net import demand is only a small part of the international market.

Several problems with this approach must also be considered. Because the equation estimated is a reduced form equation, one must recognize that several structural form models may yield the same reduced form. Hence, interpretation of parameters in a reduced form, based upon a single structural form, may lead to incorrect conclusions. What is attributed to one policy or behavioral mechanism may in fact be due to some entirely different structure unrecognized by the analyst. This means tests based on reduced-form parameters are weaker than one might initially suspect. Rejection of hypotheses when estimated reduced-form parameters are inconsistent with the hypotheses is still possible, but that rejection must be of the complete model and not a single policy presumption.

Another important problem with the net import demand approach is that parameters are policy dependent. Whenever policy changes, parameters in a reduced-form model may change, as well. Hence, the appropriate sam-

[1] This author's work has concentrated on international grain trade, where both exporters and importers consume and produce domestically a significant portion of the commodity in question. Hence, the remarks which follow are likely to be more appropriate to such cases than to cases where a commodity is produced almost entirely for export.

ple for which a net import demand model may be estimated is a period when a stable policy is pursued by government. In a world where a government's tenure may be short, or where drastic fluctuations in world market conditions force adjustments of policies by governments, appropriate sample periods for estimation of net import demands must be correspondingly short. Careful specification of the net import demand function, including variables which capture certain policy shifts—such as dummy variables shifting equations either at changes in government or when extreme world market conditions are encountered—or use of parameters which are themselves policy functions, may alleviate this problem to some extent. On the other hand, estimation of domestic supply and demand is not immune to this problem when policy interventions affect those behaviors. Also, use of the standard supply-demand approach with exogenous government influences is certainly not a solution to this problem, though a skilled intuitive market analyst may be able to do better than an econometrician in estimating trade flows under these conditions of fluctuating policy. This author feels such intuition should be subjected to econometric tests, however.

When a country's net import demand is large relative to the size of the international market, additional problems are introduced. First, it is no longer accurate to assume the world market price is exogenous to net import demand, so an identification problem arises. The net import demand equation is not a complete reduced-form equation, so some instrumental variables estimation procedure must be utilized, requiring the determination of appropriate instruments. If the trader's market position results in oligopolistic behavior, even more serious problems occur. It is well known that a supply equation for a monopolist or oligopolist does not exist, since behaviors depend upon the slope of the demand curve. Hence, in such cases it is unlikely that a net import demand function, which is equivalent to a net supply or demand equation in the international market, will exist for an oligopolistic or monopolistic trader. More explicit and complete models of oligopolists, such as the one suggested by Alauoze, Watson, and Sturgess for the world wheat market when the major exporters hold significant stocks, must be utilized for both estimation and market simulation.

Finally, one must recognize that the data used in estimation of a net import demand function is often measured only approximately. Production and population data, for example, are often little more than time trends altered by limited information. Hence errors in variables problems are likely to bias parameter estimates. This author has also found that, in practice, relatively large estimation errors are often found for parameters of such models.

The conclusion one should draw from these problems is not that estimation of net import demand models should be abandoned in favor of the more standard spatial equilibrium framework. Rather, some integration of results from the two approaches is desirable, and the spatial equilibrium framework remains the best way to treat problems introduced by the large transport costs for commodity trade. Several approaches to this integration are possible.

One way to utilize the estimates of net import demand models in conjunction with the spatial equilibrium models is to use evidence from the net import demand models to identify countries where the supply-demand residual approach is inadequate and to use that evidence to specify appropriate constraints. This procedure is most appropriate when the net import demand models suggest trade is not dependent upon the world price. When those models suggest some response to the world market price which is inconsistent with the assumptions of the spatial equilibrium framework, either the parameters in the domestic supply and demand equations can be adjusted, as suggested by the net import demand parameters and/or an assumed underlying structure, or domestic supply and demand equations should be reestimated including the world price in place of domestic prices. Either of these procedures is likely to be subject to many problems and must be thought of as ad hoc approaches. A more sophisticated approach will be suggested in the next section of this paper.

Finally, one may substitute the net import demand equations in place of domestic supply and demand equations in determination of the constraints of the spatial equilibrium problem where the results of hypothesis tests suggest that procedure is appropriate. Such a model would amount to a combination of the USDA model, where it is most appropriate, and the model of Shei and Thompson, which is a spatial equilibrium model utilizing net import demand functions in place of domestic supply

and demand equations. This procedure is appropriate only when problems with estimation of a net import demand model representing a country's current policies are overcome.

Structural Form Models

The obvious alternative to the estimation of a reduced-form model, such as a net import demand function, is the estimation of a complete structural model. If that model is to include endogenously the role of government, then government must be introduced explicitly as a behavioral agent in the model. Specification of such a model would require a thorough understanding of the nature of government policy intervention, including policy instruments used and factors affecting such policies. One example of such a structural model is the inclusion in the standard supply-demand framework of equations explaining government price-setting policies maintained by tariffs, quotas, taxes, subsidies, or stock holding activities as instruments. Abbott (1979) has presented the structure of such a model in order to derive its implications for interpretation of a net import demand model. Direct estimation of an additional structural equation would need to be carried out for such a model.

The advantage of a complete structural model is that it would allow direct statistical investigation of hypotheses concerned with the role of government intervention in commodity markets, leading to a better understanding of the behaviors implicit in some of the less direct approaches. More direct tests of the hypotheses suggested by Abbott (1979) would be possible, allowing stronger conclusions. The process of model specification would be likely to lead to a better understanding of the underlying motivations for and actual consequences of the practical operation of government interventions in commodity markets. Such structural models also would be integrated easily into the spatial equilibrium trade models. Either supply and demand equations as functions of the world market price could be derived, or the policy models could be included directly as additional constraints to the spatial equilibrium problem.

The appeal of a structural framework as a means for endogenization of the role of government must be tempered by some of the problems likely to be encountered in the estimation of those models. First, the additional work required to specify the behavior of government and its effect on supply and demand is not insignificant. Far greater knowledge of policy interventions and their operation is required of this approach than for the simpler net import demand approach. Political hypotheses and their consequences cannot be avoided. In addition, respecification and reestimation of supply and demand equations may be required in many instances. In some cases, the inclusion of an additional behavioral agent, the government, may introduce an identification problem where short-run supply inelasticity previously had been invoked to allow the use of simpler estimation techniques. Thus, recognition of the endogenous role of governments may invalidate use of some of the wealth of previous work used to formulate trade models. This problem is unlikely to be of major significance, but it cannot be overlooked.

The specification of structural models with an endogenous government sector may not always be best accomplished through the addition of another behavioral agent and equation. In some cases, parameters in supply and demand equations may be policy functions themselves, requiring varying parameter estimation techniques. For example, Houck, Ryan, and Subotnick have argued that one consequence of U.S. support price policies is to reduce the supply elasticity of U.S. farmers in cases where the policy would seem irrelevant. A complete structural model would need to include such effects.

Choice of an appropriate sample for estimation of these structural models would also be a problem. The problem mentioned for net import demand models, that parameters must correspond to a consistent policy if they are to be truly constant, must also be recognized for structural models. Use of varying parameter models and broader policy models which do not simply reduce to net import demand models would alleviate this problem to some extent, but not entirely.

Another problem would be due to the problems of estimation when unobserved variables are part of a model. Abbott (1979) presented a policy model where urban rather than national prices are the targets of government intervention. This author's model also included a market segmentation hypothesis, based on the enclave models of development economics. In such cases, demand equations for only a segment of the market are relevant, and yet in

most cases only national data is available. This specification at least introduces an error in variables problems for estimation, and some parameters may simply not be measurable.

Finally, oligopolistic market behaviors make integration of these structural models into the spatial equilibrium framework considerably more difficult. This author (1976) has argued that it would be better to estimate a price-setting equation for the Canadian Wheat Board when significant stocks are held rather than to estimate either a net import demand function or to use trade as the difference between domestic supply and demand. That behavior could be included as a constraint in the spatial equilibrium framework, but a more complete model of the oligopoly is more likely to predict market shares for the oligopolists accurately. The consequences of such market structures and models, therefore, should be treated explicitly in commodity trade model estimation.

Conclusions

In this paper, two approaches to the endogenization of the role of government into commodity trade models have been discussed. The logic behind government interference has been used as a means to interpret net import demand models and has then been extended to suggest structural form models that support such interpretations. Advantages and disadvantages with each approach have been discussed, with emphasis on the resulting econometric problems. At this point in time it makes no sense to attempt to choose between these approaches because they complement each other, and there is too little evidence to predict success for the structural approach in practice.

The simplicity of the net import demand approach is a persuasive reason for its continued use. The interpretation of the role of government and its consequential effect on parameters in these models, discussed here and elsewhere by this author, are important in providing one explanation of the results obtained for these net import demand models and, particularly, in explaining discrepancies between that approach and the traditional spatial equilibrium approach. Many problems, particularly for interpretation of parameter estimates in net import demand models, must be recognized, however. Hence, cautious interpretation of results is required.

The completeness of the structural approach and the ability to test hypotheses in that framework more directly, suggest that approach as a logical extension of the net import demand models. Some, but not all, of the problems inherent in interpretation of estimates in net import demand models are solved by this approach. The amount of work and additional information required by the structural approach suggest that its adoption should proceed where important hypotheses concerned with the influence of government on commodity market outcomes can be identified. The results then should be integrated more fully into either the net import demand approach or the spatial equilibrium approach.

Finally, this paper has suggested that a combination of either the net import demand approach or the structural approach with the traditional spatial equilibrium framework is possible. In addition, these two approaches allow econometric tests of the adequacy of the spatial equilibrium assumptions and of the hypotheses suggested by this author. Because the spatial equilibrium framework handles well many analytical problems that arise in modeling commodity trade, integration of these approaches is desirable.

References

Abbott, P. C. *Developing Countries and International Grain Trade*. Ph.D. thesis, Massachusetts Institute of Technology, 1976.

———. "Modeling International Grain Trade with Government-Controlled Markets." *Amer. J. Agr. Econ.* 61(1979):22–31.

Adelman, M. A. *The World Petroleum Market*. Baltimore, Md.: Johns Hopkins University Press, 1972.

Alaouze, C. M., A. S. Watson, and N. H. Sturgess. "Oligopoly Pricing in the World Wheat Market." *Amer. J. Agr. Econ.* 60(1978):173–78.

Bawden, D. L. "A Spatial Equilibrium Model of International Trade." *J. Farm Econ.* 48(1966):862–74.

Berntson, B. L., O. H. Goolsby, and C. O. Nohre. *The European Community's Common Agricultural Policy*. USDA ERS For. Agr. Econ. Rep. No. 55, 1969.

"Chief U.S. Trade Negotiator at Geneva Calls Farm Products Still a Central Snag," *Wall Street Journal*, 11 July 1978, p. 5.

Houck, J. P., M. E. Ryan, and A. Subotnik. *Soybeans and Their Products: Markets, Models and Policy.* Minneapolis: University of Minnesota Press, 1972.

McCalla, A. F. "A Duopoly Model of World Wheat Pricing." *J. Farm Econ.* 48(1966):711–27.

Shei, S. Y., and R. L. Thompson. "The Impact of Trade Restrictions on Price Stability in the World Wheat Market." *Amer. J. Agr. Econ.* 59(1977):628–38.

U.S. Department of Agriculture, Economic Research Service. *World Demand Prospects for Grain in 1980 with Emphasis on Trade by Less Developed Countries.* For. Agr. Econ. Rep. No. 75, Dec. 1971.

Discussion

W. C. Labys

The paper by Johnson, Grennes, and Thursby attacks a problem of considerable importance: how to make commodity models agree more closely with reality. Differences in prices both spatially and across similar commodities have long been recognized by commodity economists. In addition to the transfer cost explanation of spatial price differences, there are also institutional factors which have caused spatially differentiated prices to covary to a lesser or greater degree over time, such as, for example, the organization of central banks in commodity-exporting, developing countries. The evidence presented by the authors on theories of price elasticities and substitution deals more with applications of received theory than with the suggestion of functional relationships which describe the actual nature of commodity substitution. It should be noted that substitution occurs for technical and quality or taste reasons as well as for economic reasons and such factors should be incorporated into any attempt to explain substitution between primary commodities. Concerning the authors' application of the Armington model, I concur with their difficulties of using the Armington demand structure for disaggregated commodity groups. Assumptions underlying the cross-price elasticities also are difficult to satisfy in using systems of demand equations to analyze domestic substitution, e.g., see Labys (1977). However, extensions of this type do offer promise, and I look forward to viewing the results of their wheat modeling effort.

The Blandford and Lee paper addresses itself initially to a rather general analysis of the various quantitative methods employed in analyzing international commodity stabilization policy. In the first part of the paper, the authors fail to make more than a few comments specifically related to primary commodity modeling. They have omitted such issues as the change in price expectations and risk response anticipated once stabilization begins, the interaction between private and public stockholding, and the impacts of functional forms on welfare measurements. An analysis of such issues as well as a review of existing econometric stabilization studies appear in two papers of mine (1978 a,b), to which the authors might refer. The authors also consider the work pursued by Waugh-Oi-Massel and Turnovsky as empirical studies of stabilization. As recently emphasized by Just and Hallam, these works rather provide the theoretical background which econometricians can draw upon to improve empirical analysis.

These comments aside, I found the second half of the paper, directed to the issues of the identification of systematic and stochastic disturbances in market systems, highly useful. This paper could be developed better by concentrating on this topic alone. Not only is the question of designing disturbance experiments highly relevant, but there is also the question of using them to describe market fluctuations more realistically. In spite of suggestions by Maunder and others to employ distributions simulating climatic patterns in commodity demand and supply relations, very little work of this type has been carried out. There also has not been much work on identifying the time-series processes underlying systematic and non-systematic commodity disturbances. In this respect, spectral analysis might prove useful. Incorporating into the paper more commodity-specific examples of disturbance processes would further enhance its value.

The Abbott paper addresses itself to a very important problem in modeling domestic and international commodity markets, that of the endogenization of government behavior. Of the two approaches suggested for incorporating this behavior, I would prefer the one which sets the government as a behavioral agent in a more complete model. The alternative approach, or net demand model, incorporates government behavior only in the context of interpreting the reduced form. Zusman was able to accomplish this in his model of the

---

Walter C. Labys is a professor in the College of Mineral and Energy Resources, West Virginia University.

Israeli sugar market based on the theory of differential games. But the mathematical formulation of the model was quite complex, and solutions for more than the six-equation model he computed might indeed prove difficult.

Possibilities for including government behavior directly in structural form equations have been demonstrated in the work of Frey. Luterbacher, Lambelet, and I in 1976 attempted to apply his approach to commodity models. Basically, this requires incorporating the work of quantitative political scientists concerning the use of political indicators and responses into econometric models. Given the difficulty of measuring political and government phenomena, our most recent effort (1978) moves only a small distance in achieving complete endogenization of government behavior. But we do feel that such an approach eventually will be of value.

Discussion

Robert M. Stern

In thinking about the modeling of commodity markets, one's initial reaction is that it should be comparatively easy because the products involved are homogeneous and often traded in organized markets under conditions of competitive efficiency. Yet the closer one gets to actual markets, the more one realizes how complex the modeling of market behavior may become. This is all the more true when there is extensive government intervention in particular markets. While the modeling of commodity markets thus poses many problems, the need for understanding these markets has increased greatly in recent years with the rapid acceleration of inflation, the formation of producer cartels, and the call for higher and more stable prices for commodities as part of the New International Economic Order.

An interesting and important issue that has been addressed in the paper by Johnson, Grennes, and Thursby is whether commodity markets can be distinguished from markets for industrial products in terms of product homogeneity or heterogeneity. It is common in trade theory to assume that products are homogeneous, and, in the monetary approach to the balance of payments, commodity arbitrage is assumed to take place, which will insure that the law of one price will hold. In this regard, there have been a number of recent studies of the characteristics of internationally traded products that suggest important departures from the assumptions of product homogeneity and the law of one price. Why is this?

Johnson, Grennes, and Thursby note that spatial price differences may arise because of transfer costs between markets and because of intertemporal variations in production and demand among countries. Furthermore, prices may differ for particular products in a given market because of product differentiation, information costs, and for statistical reasons because of aggregation problems. The former two explanations of price differences have been treated elsewhere in the literature under the rubric of "experience" versus "search" goods. This is a rather interesting distinction that might be explored further in investigating price behavior in order to identify the structural factors that may distinguish the different types of goods and how these factors change through time in terms of the price differentials observed. In light of the theory of the product cycle, for industrial goods at least, one might expect price spreads to diminish. Presumably the same thing should apply to commodities.

Abbott notes in his paper that patterns, techniques, and objectives of government intervention may vary a good deal among countries and through time. Such intervention constitutes another important reason why prices may differ, and, to the extent that policies change, the differentials may vary. The Johnson, Grennes, and Thursby and Abbott papers thus suggest that an interesting next step in research would be to attempt to explain the reasons for persistent price differences and for variations in these differences for particular commodities and commodity groups. I would surmise that such research would be helpful in suggesting appropriate techniques for modeling behavior in different markets.

Turning now to questions of modeling, Abbott is to be commended for his efforts in endogenizing government behavior. By the same token, his empirical proxies for government intervention are not altogether clear in terms of the objectives and consequences of government policies in different countries. At best, his research points up the limitations of the spatial-equilibrium-model elasticity estimates. Yet his empirical work stops far short of providing convincing estimates of endogenous government behavior. In pursuing this question further, it seems to me that classical regression procedures may not be well suited to the undertaking. And it might be desirable, moreover, to study a few countries in depth rather than to impose a simplified model across a wide variety of countries.

Johnson, Grennes, and Thursby devote a

Robert M. Stern is a professor in the Economics Department, University of Michigan.

substantial part of their paper to an elaboration of the Armington model, and, in this respect, their reliance on this model seems unbalanced. They take note of the properties of the Armington model and its important restrictions with respect to cross-price and expenditure elasticities. I might note parenthetically that knowledge of these restrictions predates Armington, as will be clear from the literature on estimating the elasticity of substitution discussed in chapter 3 of Leamer and Stern's 1970 book, *Quantitative International Economics*. In contrast to their elaboration of the demand side of their model, Johnson, Grennes, and Thursby treat supply as exogenous. This is perhaps understandable in a short-run context and in view of the difficulties of modeling the supply side, but it is unfortunately not always elucidating in enhancing our understanding of the market behavior at issue. In discussing applications and extensions of the model, Johnson, Grennes, and Thursby make reference to handling changes in policies. Space did not permit them to indicate precisely how this is to be done, whether from the demand or supply sides. Unless both sides were modeled effectively, it is not clear what degree of confidence one might have in the results.

Finally, let me make a couple of brief remarks on the paper by Blandford and Lee. They mention the importance of nonsystematic factors, and I would presume that government intervention might be one example of what they have in mind. In constructing commodity models, it is obviously important to assess the significance of nonsystematic factors. This is particularly the case because if, as noted above, intervention policies vary so much, it may be extremely difficult to construct reliable models that can in turn be used with a high degree of confidence in evaluating different proposals for stabilization. I would also like to take note of the possibility of being carried away with the analysis of instability per se, when the real issue, particularly in the call for a New International Economic Order, is how to transfer more resources from consuming to producing countries. If this perception is correct, the policy rules for intervention or the objective functions of policy makers that are to be used in commodity models need to be revised accordingly.

Reference

Leamer, Edward E., and Robert M. Stern. *Quantitative International Economics*. Boston: Allyn and Bacon, 1970, pp. xii, 209.

A Modeling Approach to Flows of Funds in Localized Financial Markets

Michael Boehlje, Duane G. Harris, and James Hoskins

The rapid growth in the capital and credit requirements of the agricultural sector has generated concern about the ability of financial institutions, particularly commercial banks, to service effectively that sector. In recent years, commercial banks in rural areas have encountered simultaneously increases in loan demand and changes in competition and saver behavior that have increased the cost and reduced the supply of loanable funds obtained as deposits from local sources. To evaluate the impact of such changes in the competitive environment of the banking industry or in regulations that affect banking structure, it is essential to determine the impact of those changes on the flow of funds in local markets.

Yet the determinants of and factors influencing funds flows within and between local markets are not well understood. Numerous studies have been completed, for example, on the implications for competition and funds flow of changes in bank structure regulations (Mote, Guttentag and Herman). Most of these studies have been descriptive, with limited recognition of either the supply of and demand for funds in various markets or the transactions costs of management constraints that would impede or encourage funds flows between markets and regions. In addition, one of the striking characteristics of these studies is the inconsistency of their results. For example, some analysts indicate that changes in branch banking or holding company regulations result in a decline in lending activity for farmers, and thus a flow of funds from rural to urban areas (Lee and Reichert, Sullivan). Others indicate that changes in bank structure result in increased lending activity with local borrowers, including farmers (Snider, Rosenblum, and Eisenbeis).

Spatial allocation models that explicitly incorporate supply and demand functions have been used widely in the agricultural sector to analyze commodity flows between various markets and geographic regions as well as the implications of government intervention on such flows (Heady and Srivastava). The purpose of this article is to examine the potential for use of spatial allocation modeling techniques to evaluate the flow of funds within and between local financial markets. The unique structural dimensions of the methodology will be reviewed, data needs for related empirical work will be discussed, and an evaluation will be presented.

Conceptual Model

If one views the funds that flow from savers to investors as commodities with unique supply and demand functions, risk and maturity characteristics, and transaction costs, spatial price and allocation models can provide a conceptual and mathematical base for empirical analysis of funds flows in local markets. The following model formulation assumes that financial intermediaries can acquire funds from spatially separated markets and allocate them to meet final product demand (loans, investments, reserves) in those or alternative markets. From a policy perspective, the objective of such allocation and acquisition activities is assumed to be to maximize a constrained aggregate net profit function. Maximize

$$(1)\quad \sum_i\sum_u(\alpha_{iu} - \beta_{iu}Y_{iu})Y_{iu} - \sum_j\sum_v(\delta_{jv} + \theta_{jv}X_{jv})X_{jv} - \sum_i\sum_j\sum_k\sum_l \tau_{ijkl}Z_{ijkl} - \sum_a\sum_i\sum_j\sum_k\sum_l \phi_{ijkl}\Phi^{a}_{ijkl} - \sum_i\sum_j\sum_k\sum_l \phi_{ijkl}\P_{ijkl},$$

subject to

Michael Boehlje is a professor and Duane G. Harris is an associate professor in the Department of Economics at Iowa State University. James Hoskins is a research analyst, headquarters, U.S. Air Force.

Journal Paper No. J-9300 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, Project No. 2066.

Peter J. Barry provided useful comments on an earlier draft of this article.

(2) $\sum_j \sum_l \gamma_{ijkl} Z_{ijkl} \geq Y_{iu}$,

(3) $\sum_i \sum_l \gamma_{ijkl} Z_{ijkl} \leq X_{jv}$,

(4) $\sum_a \rho^a_{ijkl} X_{ijkl} \leq \Phi^a_{ijkl}$,

(5) $Z_{ijkl} \leq ¶_{ijkl}$,

(6) $\alpha_{iu} - \beta_{iu} Y_{iu} \leq \gamma_{ijkl}[\tau_{ijkl} + \phi_{ijkl} + (\delta_{jv} + \theta_{jv} X_{jv})]$, and

(7) $Y_{iu}, X_{jv}, Z_{ijkl}, \phi_{ijkl} \geq 0$.

For the notational conventions employed, the subscripts denote: i, the demand market; l, the financial intermediary; j, the supply market; k, the transformation process; u, the financial product; a, the nonfunds resources; and v, the financial resources.

Parameters are α_{iu}, β_{ui} for the demand function for financial product u in market i; δ_{jv}, θ_{jv} for the supply function for financial resource (funds) v in market j; τ_{ijkl}, transformation costs of transferring funds from savers in market j to users in market i by transformation process k performed by financial intermediary l; γ_{ijkl}, the efficiency of transformation of funds from market i to market j through process k performed by financial intermediary l; $\rho_{ijkl}{}^a$, the per unit nonfunds resources (a) required to transform funds from market i to market j through process k performed by financial intermediary l; $\Phi_{ijkl}{}^a$, the nonfunds resources (a) available in market i or j to transform funds through process k by financial intermediary l; and $¶_{ijkl}$, policy and management constraints in market i or j on transformation process k performed by financial intermediary l.

Finally, the decision variables are Y_{iu}, the total quantity of financial product u utilized in market i; X_{jv}, the total quantity of financial resource v provided in market j; Z_{ijkl}, the quantity of financial resources transformed from market i to market j through process k by financial intermediary l; and ϕ_{ijkl}, the imputed cost of immobile resources, policy constraints, or management restrictions in market i or j on transformation process k performed by financial intermediary l.

The objective function [equation (1)] reflects net profits (total revenue minus total explicit and implicit costs) of intermediation for the industry, assumes perfect competition in the product and resource markets, and is structured to satisfy the efficiency conditions specified by Plessner. This objective function is maximized subject to the constraints of equations (2)–(6). Equation (2) indicates that the quantity of funds transformed into final financial products (u) for market i must be greater than or equal to the quantity of financial products demanded. Equation (3) indicates that the quantity of funds transformed from financial resources (v) in market j must not exceed the supply of financial resources. Equation (4) reflects the fact that the process of transforming and allocating funds is limited by the quantity of nonfunds resources (manpower, equipment capacity, etc.) available. Constraints on funds transformation [equation (5)] are also imposed by the management of various financial intermediaries as well as by policies of regulatory authorities. Finally, equation (6) imposes the constraint that the price per unit of the financial product cannot exceed the per-unit-of-product costs of transformation and intermediation, the cost of the financial resources, and the imputed cost of the nonfunds resources and management and policy constraints. Thus, the results of an empirical solution of the model would indicate the funds flows between and within markets as well as the equilibrium prices for funds in various markets and geographic regions.

Components of a Flow of Funds Model

To evaluate the potential for implementation of a spatial equilibrium model for local financial markets, it is necessary to estimate empirically the parameters for the structural components. This includes the delineation of local financial markets, estimation of supply and demand functions for funds in local markets, specification of an appropriate objective function and pricing constraint to reflect the competitive environment, determination of transactions costs associated with funds flows, and the identification of management and regulatory constraints that impinge on commercial bank management.

Delineation of Local Markets

A banking market can be defined as the area encompassing all those banks that exert and react to essentially the same set of competitive forces influencing the price or quality of a specific product or service. Such an area must

be conceptually distinguished from a bank service area. A service area outlines the geographic region from which a bank draws most of its customers. As such, a service area can be viewed as a subset within a market area.

Several procedures have been proposed and used to delineate economic areas that are supposedly relevant to market analysis. Geometric spatial configurations are analytically appealing but difficult to apply empirically to bank market delineation. Techniques such as customer spotting, license plate analysis, and the gravity model are approaches that delineate service areas rather than market areas. Political and other ad hoc boundaries, such as city, county, or SMSA areas, have been used widely as proxies for market areas because of data availability. But such boundaries are arbitrary delineations usually resulting from political decisions that may have little to do with banking markets.

The delineation procedures that rest on sound economic principles and yet have potential for useful implementation are those based on cross-demand schedules or cross elasticities. Glassman defines a banking market as a "region in which the cross elasticity of demand for banking services within the region is significantly higher than that existing between banks in the region and banks outside the region" (p. 22). But, as Cochrane has pointed out, the cross-demand approach may be operationally impossible to implement. He argued that the necessary price-quantity data to estimate cross-demand schedules may be unavailable, or if available, prohibitive in cost.

Mathis, Harris, and Boehlje, in response to Cochrane's criticisms of the cross-demand approach, developed a delineation procedure based on response times between price adjustments on time deposits at commercial banks. The procedure used interest rate response data to classify banks as either rivals or nonrivals. Data requirements are substantially less than for cross-elasticity estimation, although data must be obtained on all banks that are to be grouped into markets.

Thus, several approaches exist for the delineation of markets to use in a spatial equilibrium model. Unfortunately, those procedures with the sounder economic base are likely to be the most data-intensive and costly to implement. Tradeoffs likely will have to be made between economic purity and data cost if the researcher is to complete the delineation phase of a flow of funds modeling analysis.

Market Supply and Demand for Funds

A number of researchers have identified and empirically evaluated the determinants of aggregate deposit supply and loan demand (Karbouche, Penson, Lins, Hesser and Schuh) for the United States or the agricultural sector. Little previous work has been completed on the demand and supply of funds in local financial markets. Two recent attempts at empirical estimation of such relationships illustrate the problems and opportunities. Boehlje and Fisher estimated loan demand and deposit supply equations for banks by using ordinary least squares on data for the years 1961 to 1972 from eighteen rural Oklahoma counties. The estimated equations indicate that income and the rate on time deposits as well as the rate on alternative uses of funds (corporate bonds) are important determinants of local deposit supply and that income, retail sales, farm prices, and weather conditions as well as interest rates are major determinants of loan demand in local rural markets. Although the statistical properties indicate that the estimated equations are acceptable as first approximations of the determinants of loan demand and deposit supply, data on interest rates, in particular, were difficult to acquire and consequently were obtained from secondary sources rather than from observations at the local market level.

In an attempt to obtain more accurate estimates of loan demand using disaggregated data, Hoskins estimated the demand for agricultural loans at rural commercial banks using cross-sectional data for sixty-one counties in Iowa for the year 1975. Implicit interest rates were calculated from bank income statement data based on interest income and loan volume. Preliminary analyses using ordinary least-squares estimation procedures indicated that 98% of the variation in county volume of agricultural production loans in December can be explained by variations in interest rates on agricultural production loans, county taxable income for the year, and county volume of agricultural production loans in June.

The Degree of Competition in the Market

The formulation of equations (1)–(7) implies a perfectly competitive market where maximum net profit is zero, because, by the constraint in

equation (6), the price of final financial products in each market is less than or equal to the marginal cost of that product in each market. Some analysts, however, have characterized local financial markets as being less than perfectly competitive; and, in fact, many of the policy and regulatory changes one might want to evaluate with the proposed methodology will influence the degree of competition in local financial markets. Hoskins, Plessner, and Maruyama and Fuller discuss alternative formulations of the spatial allocation model that will accommodate varying degrees of competition. In essence, in the case of pure monopoly, such formulations modify the objective function to include negative monopoly profits as an implicit cost, and modify the pricing constraint [equation (6)] to reflect the condition that marginal revenue must not exceed marginal cost. Denoting monopoly profits as $\sum_i \sum_u \lambda_{iu} \zeta_{iu} Y_{iu}$, and marginal revenue as $\alpha_{iu} - 2\lambda_{iu}\beta_{iu}Y_{iu}$, where λ_{iu} denotes the degree of competition ($\lambda_{iu} = 0$ denotes pure competition in the i^{th} market for product u, and $\lambda_{iu} = 1$ denotes pure monopoly), and ζ_{iu} indicates the monopoly profit per unit of financial product u in market i, the objective function becomes:

$$(1') \quad \sum_i \sum_u (\alpha_{iu} - \beta_{iu} Y_{iu}) Y_{iu} - \sum_j \sum_v (\delta_{jv} + \theta_{jv} X_{jv}) X_{jv} - \sum_i \sum_j \sum_k \sum_l \tau_{ijkl} Z_{ijkl} - \sum_a \sum_i \sum_j \sum_k \sum_l \phi_{ijkl} \Phi^a_{ijkl} - \sum_i \sum_j \sum_k \sum_l \phi_{ijkl} \P_{ijkl} - \sum_i \sum_u \lambda_{iu} \zeta_{iu} Y_{iu},$$

and the pricing constraint becomes

$$(6') \quad \alpha_{iu} - 2\lambda_{iu}\beta_{iu}Y_{iu} \leq \gamma_{ijkl}[\tau_{ijkl} + \phi_{ijkl} + (\delta_{jv} + \theta_{jv}X_{jv})].$$

Hoskins indicates that parameterization of λ_{iu} can be used to reflect varying degrees of competition between pure monopoly ($\lambda_{iu} = 1$) and pure competition ($\lambda_{iu} = 0$). Note, however, that the precise definition of these various degrees of competition is not possible.

Transaction Costs and Management Constraints

The constraints of equations (5) and (6) require that information and data be obtained on transformation and intermediation costs and policy and management constraints. Transformation and intermediation costs can be grouped into two categories—those associated with existing resources and services and those associated with new technological developments in banking.

Transaction costs of existing resources and services could be best approximated from functional cost data collected by the Federal Reserve System. Banks could be stratified by size, geographic location, organizational structure, etc., to estimate cost averages for different financial products. Costs associated with new technological developments would have to be approximated from secondary sources or from use of industry intelligence and judgment.

Management and policy constraints also can be grouped into two categories—those originated by internal bank management and those imposed by legislative bodies and regulatory authorities. Internal management constraints may take the form of maximum loan-deposit ratios, limits on particular classes of loans or investments, particular portfolio restrictions to provide for liquidity, redlining policies, etc. Data on typical management policies would have to be obtained from primary survey work, or the model could be tested by using different assumptions about management policy constraints. Regulatory measures include such constraints as maximum loan limits to a particular customer, branching, and holding company restrictions, Regulation Q, and usury ceilings. Data on such constraints would be obtained directly from published regulatory decisions or legislative statutes.

Evaluation of the Methodology

The spatial allocation approach to flow of funds analysis possesses a number of desirable attributes. First, the method explicitly recognizes the structural form of financial markets and specifically includes those variables that are important in describing that structure. The approach allows the analyst not only to describe funds flows on an after-the-fact basis but also to evaluate the causes or determinants of funds flows and to prescribe future flows of funds that are optimal with respect to the specified objective functions. Consequently, information from such a methodology includes both the optimal pattern of funds flows between markets and the equilibrium prices for sources and uses of funds in various geo-

graphic regions. Additionally, the implicit costs of internal management constraints and external regulatory and policy constraints that influence flows of funds can be evaluated explicitly. For example, the costs of particular risk preference or satisficing behavior of bank management could be examined. Or, the impact on flow of funds of legislative mandates such as usury ceilings could be determined.

The methodology contains sufficient flexibility to accommodate wide variations in market delineation, institutional alternatives (banks, savings and loans, credit unions), savings and investment instruments (deposits and loans and investments with various risk, maturity, and return characteristics), and management and regulatory constraints. It also allows an analysis of proposed changes in the financial environment preceding the implementation of those changes.

For example, the implications for funds flows and equilibrium prices of a proposed holding company acquisition, changes in branching regulations, improvements in the secondary markets for insured or guaranteed loans, or introduction of electronic funds transfer could be evaluated. Such proposals could be examined through changes in the transaction costs of moving funds from one market to another or through changing the competition parameters in the objective function and pricing constraints.

Also, policy proposals that would directly affect credit allocation to certain sectors of the economy could be included in the constraint or activity set of the model. Antiredlining proposals that mandate credit allocation to areas that are supposedly not adequately serviced and policy options that would subsidize lending activity to a particular industry such as agriculture or small businesses in rural communities could be analyzed. The addition of temporal dimensions to the model to reflect seasonality in demand and supply for funds could assist in assessing funds flows between markets experiencing short-term surpluses and deficits.

Certainly, the proposed methodology possesses some disadvantages as well. Specifically, data needed to implement the spatial allocation model are demanding. But, data requirements for spatial equilibrium analyses in other industries have been met, so it should be possible for the financial sector as well. Preliminary empirical work suggests that the most serious data limitation is an inadequate interest rate series. Because interest rates have been shown to be a good proxy for all borrowing costs (Harris), a reliable interest rate series could substantially improve researchers' ability to delineate markets and to implement flow of funds models. Examining agencies in particular might easily collect interest rate data as a part of their examination process, and most accounting systems used by commercial banks could be modified easily to generate time-series data by day, week, or month on interest rates paid on deposits and charges on various loan categories, as well as levels of deposit balances. Data on other determinants of loan demand and deposit supply, such as consumer income and business conditions, can be obtained from secondary data sources in many cases. Management constraints unique to an individual financial intermediary would require primary survey data. With the adoption of new technology such as electronic funds transfers, additional research will be needed on the estimation of transactions costs.

A second problem is the set of simplifying assumptions necessary for modeling the financial intermediation and flow-of-funds process. In particular, the assumption of profit maximization as well as the assumptions underlining the constraints imposed to reflect risk aversion may result in distortions when the model results are compared with reality. A significant amount of econometric and estimation work is needed to implement the model, and one might be tempted to use sensitivity analysis on those parameters not easily estimated, to determine the impact of various values for those parameters on the resulting flow of funds and equilibrium prices. Certainly such parameterization may be useful, but one must not substitute sensitivity analysis for a solidly based empirical estimate of model parameters.

As is frequently the case, the price one must pay for using a method that enables the researcher to understand the structure of an economic system and obtain at least partial explanations of changes in various economic phenomena (flow of funds, equilibrium prices, and quantitites supplied and demanded in our case) is the necessity to acquire and analyze a substantial quantity of data. Success in the application of spatial allocation models to other industries should give encouragement to

researchers interested in applying them to the financial sector.

References

Boehlje, Michael, and Glen Fisher. "A competitive Management Game for Non-Metropolitan Commercial Banks." *J. Bank Res.* 7(1976):56–67.

Cochrane, Willard W. "The Market as a Unit of Inquiry in Agricultural Economics Research." *J. Farm Econ.* 39(1957):21–39.

Eisenbeis, Robert A. "The Allocative Effects of Branch Banking Restrictions on Business Loan Markets." *J. Bank Res.* 6(1975):43–47.

Glassman, Cynthia A. "Banking Markets in Pennsylvania." *Changing Pennsylvania's Branching Laws: An Economic Analysis*. Philadelphia, Pa.: Federal Reserve Bank, 1973.

Guttentag, Jack M., and Edward S. Herman. *Banking Structure and Performance*. New York: Institute of Finance, New York University, Feb. 1967.

Harris, Duane G. "Credit Rationing at Commercial Banks: Some Empirical Evidence." *J. Money, Credit, and Banking* 6(1974):227–40.

Heady, Earl O., and Una K. Srivastava. *Spatial Sector Programming Models in Agriculture*. Ames: State University Press, 1975.

Hesser, Leon F., and G. Edward Schuh. "The Demand for Agricultural Mortgage Credit." *J. Farm Econ.* 54(1962):1583–88.

Hoskins, James. "Local Agricultural Financial Markets: A Nonlinear Approach." Ph.D. thesis, Iowa State University, 1978.

Karbouche, George K. *The Competition for Savings: Determinants of Deposits at Commercial Banks, Mutual Savings Banks, and Savings and Loan Associations*, SBE 107. New York: National Industrial Conference Board, 1969.

Lee, Warren F., and Alan K. Reichert. "The Effects of Multibank Holding Company Acquisitions on Rural Banking." *Agr. Finan. Rev.* 38(1978):35–41.

Lins, David A. "Determinants of Net Changes in Farm Real Estate Debt." *Agr. Econ. Res.* 24(1972):1–8.

Maruyama, Yoshihiro, and Earl I. Fuller. "An Interregional Quadratic Programming Model for Varying Degrees of Competition." University of Massachusetts Agr. Exp. Sta. Bull. 555, Nov. 1965.

Mathis, Stephen A., Duane G. Harris, and Michael Boehlje. "An Approach to the Delineation of Rural Banking Markets." *Amer. J. Agr. Econ.* 60 (1978):601–608.

Mote, Larry R. "The Perennial Issue: Branch Banking." *Business Conditions*. Chicago: Federal Reserve Bank of Chicago, Feb. 1974, pp. 3–23.

Penson, John B., Jr. "Demand for Financial Assets in the Farm Sector: A Portfolio Balance Approach." *Amer. J. Agr. Econ.* 54(1972):163–74.

Plessner, Yakir. "Computing Equilibrium Solutions for Imperfectly Competitive Markets." *Amer. J. Agr. Econ.* 53(1971):191–96.

Rosenblum, Harvey. "The Impact of Limited Branch Banking on Agricultural Lending by Banks in Wisconsin." *Improved Fund Availability at Rural Banks*, Report and Study Papers of the Committee on Rural Banking Problems, Board of Governors of the Federal Reserve System, June 1975, pp. 115–17.

Snider, Thomas E. "The Effect of Mergers on the Lending Behavior of Rural Banks in Virginia." *J. Bank Res.* 4(1973):52–57.

Sullivan, Gene D. "Impact of Holding Companies Farm Lending by Banks in Florida." *Improved Fund Availability at Rural Banks*. Report and Study Papers of the Committee on Rural Banking Problems, Board of Governors of the Federal Reserve System, June 1975, pp. 125–29.

Incorporation of General Economic Outcomes in Econometric Projections Models for Agriculture

John B. Penson, Jr., and Dean W. Hughes

The AAEA has devoted two invited paper sessions in recent years to the econometric modeling of the farm business sector. A 1974 session dealt with the evaluation of econometric models for the farm business sector as well as for the total economy. Of particular note was the paper presented by Popkin, who cited several approaches to improving price forecasts in macroeconomic models. The attention given to price forecasting in this session was understandable in light of the inordinately high degree of price variability experienced during the 1973–74 period and the inability of existing models to forecast these fluctuations accurately. A 1976 session dealt with the interface in aggregate econometric models between the farm business sector and the general economy. Papers presented by Chen and by Roop and Zeitner emphasized the interaction between farm business sector models and a larger macroeconomic model for the U.S. economy, the Wharton econometric model. One general conclusion stemming from this session was that greater endogenization of nonfarm business outcomes would reduce the error associated with projecting farm business outcomes, and vice versa.

In discussing the papers presented in the 1976 session, Johnson alluded to the need to use functional relationships instead of identities when accounting for linkages between the economic sectors of an economy. Just further argued that sector econometric models must reflect the major interfaces with the general economy. The output, input, and international trade linkages he cites, however, represent only part of the interface between the farm business sector and the general economy. Conspicuous by its absence is the linkage between the bond and equity capital markets, financial intermediaries, and the cost and availability of loan funds to finance farm business operating expenses and capital accumulation. Also missing are most of the channels through which changes in national economic policy stimulate and direct the growth of the total economy.

This paper initially discusses the general organization of a multisector macroeconomic model for the U.S. economy. Principal emphasis in this model is on the farm business sector instead of the general economy, and on those groups of consumers who have a financial interest in the economic health of this sector. The rest of the economy is disaggregated only to the extent that its physical and financial linkages to farm businesses are accounted for. The assumption is made that specification of sector projections models should allow for the simulation of alternative national economic policies which, by definition, affect both farm and nonfarm business activity. This assumption is consistent with the observation by both Fox and Johnson that policy makers and other users of information provided by econometric projections models require answers to increasingly integrated and complex questions. Rather than using a set of identities to account for the interface between the farm business sector and the general economy, we shall identify the principal markets in which they are functionally interrelated. Because this session focuses on financial markets, the discussion of the linkages in this model is limited primarily to the linkage between private saving and the financing of farm business operating expenses and capital accumulation. Specific properties of several existing sector models will be cited to illustrate different approaches to sector modeling

---

John B. Penson, Jr., is an associate professor, Department of Agricultural Economics, Texas A&M University, and Dean W. Hughes is an agricultural economist with the Economics, Statistics and Cooperatives Services, U.S. Department of Agriculture, stationed at Texas A&M University.

Technical Article No. 14182 of the Texas Agricultural Experiment Station.

taken in past studies. Particular attention is given to the measures of factor costs used in previous econometric studies of aggregate investment behavior and the need to account for the full rental price of capital.

Multisector Macroeconomic Models

The macroeconomic models presented in most economic textbooks have several features in common. For example, these models generally have one aggregate production function, one group of homogeneous consumers who allocate their disposable income between saving and consumption, one labor market, a money market, and a government budget constraint. To account for the complete interface between the farm business sector and the general economy, however, we must (*a*) have at least two production functions, two labor markets, and two final product markets to separate farm and nonfarm business activity; (*b*) partition consumers according to whether or not they have a financial interest in the farm business sector; (*c*) distinguish between the alternative sources of external financing to farm and nonfarm businesses; and (*d*) identify the markets in which different financial intermediaries obtain their loanable funds.

Model structure

The structure of the macroeconomic model discussed in this paper is illustrated in figure 1. Businesses in the economy have been allocated sectors by product lines. All resources used to produce raw agricultural products are included in the farm business sector regardless of where their ownership lies. The same approach has been taken in the nonfarm business sector which, among other functions, processes and distributes intermediate goods acquired from the farm business and rest-of-the-world sectors. The farm and nonfarm business sectors are directly linked by three sets of markets: (*a*) domestic raw agricultural products markets, (*b*) domestic manufactured farm inputs markets, and (*c*) farm input rental markets, where the services provided by capital leased by farm operators from nonfarm businesses and nonoperator landlord families are acquired. The farm and nonfarm business sectors are also linked in the farm real estate market when nonfarm businesses desire to purchase farmland for nonagricultural purposes from discontinuing proprietors.

In addition to its linkage with the farm business sector, the nonfarm business sector is linked to a set of domestic consumer groups by the final markets for agricultural and nonagricultural products and by a household asset rental market. This set of domestic consumer groups consists of farm operator families, nonoperator landlord families, hired farm labor families, and "other domestic consumers." The first three groups have been targeted for special consideration because of the unique effect that farm business sector outcomes have upon their demand for goods and services. The domestic consumer groups, in turn, supply labor services to farm and nonfarm businesses, governments, and financial intermediaries in return for wages, salaries, and royalties. These groups also receive income from farm and nonfarm investments in the form of proprietary income, dividends, and interest.

A rest-of-the-world sector, which imports goods purchased from nonfarm businesses in the U.S. final agricultural and nonagricultural products markets and exports intermediate goods to the U.S. nonfarm business sector, is also included in the model. When the nonfarm business sector takes delivery of imported intermediate goods, it processes and distributes them in either the final agricultural or nonagricultural products markets.

The interfaces identified above do not differ appreciably from the output, input, and international trade interfaces discussed by Just. By incorporating these linkages in our macroeconomic model, we can account for the effects of relative price changes on the farm business sector. Just's specific call for additional research on the relative importance of the farm business sector in determining U.S. trade balances and exchange rates merits reemphasis and could be accommodated in a macroeconomic model such as that depicted in figure 1.

What of the many financial linkages between the farm business sector and the general economy, such as the transfer of funds by financial intermediaries from savers to those farm operator families needing external financing to purchase farm business assets? Annual farm business capital accumulation once was financed almost entirely with internal equity capital. Penson (1977) has shown, however, that as much as one-half of annual farm busi-

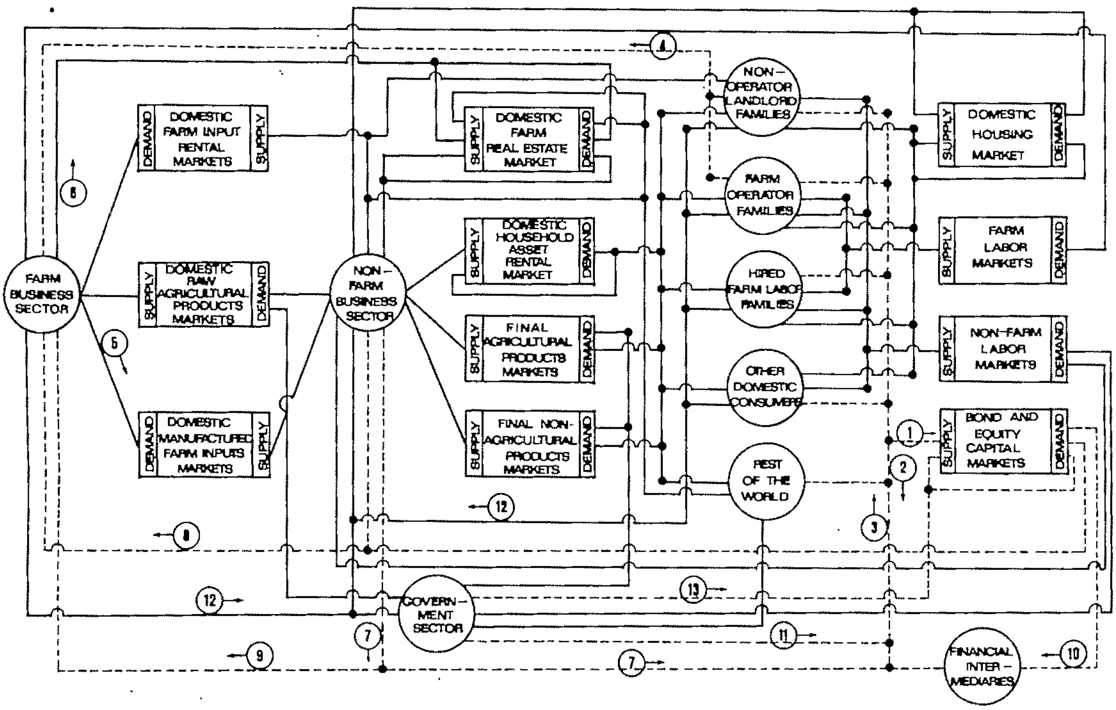


Figure 1. Physical and financial linkages between agriculture and the general economy

ness capital accumulation by farm operator families in recent years has been financed with external capital. What of the government sector's monetary and fiscal policies and their effect on physical and financial flows both within and between the farm business sector and the general economy? Schuh recently argued that greater attention must be given to examining monetary and fiscal policies if we are to understand fully the changes taking place in the farm business sector and the macroeconomy, and to project accurately future sector economic outcomes. What of alien investment in U.S. farm and nonfarm business assets or the outflow of dollars invested in other countries? We argue that these and other financial interfaces must be endogenized along with those identified by Just in econometric models purporting to project the economic and financial performance of the farm business sector under alternative national economic policy regimes.

Financial interfaces

To better understand the need to endogenize these financial interfaces in modeling the farm business sector, let us examine the linkage between savers in the economy and the financing of farm business operating expenses and capital accumulation. The channels through which these funds flow are indicated by the dashed lines in figure 1. For example, each of the domestic consumer groups and the rest-of-the-world sector either invests funds in the bond and equity capital markets (#1) or places funds on deposit at commercial banks and other deposit-based financial intermediaries (#2). These consumer groups also repay their existing loans (#2) and borrow new loan funds (#3). One of the reasons nonoperator landlord families and farm operator families borrow is to supplement their internal equity capital when financing the purchase of farm business assets (#4) in either the manufactured farm input markets (#5) or the farm real estate market (#6). Merchants and dealers also provide debt financing to farm operator families who purchase manufactured farm inputs (#7). A relatively small number of incorporated farm businesses also acquire external financing by selling debt and equity instruments in the bond and equity capital markets (#8) as well as by borrowing directly from financial intermediaries (#9). Some financial intermediaries such as the Farm Credit System obtain their new loanable funds by issuing debt instruments in the bond markets (#10). The gov-

ernment sector, principally in the name of the Farmers Home Administration, also provides loan funds to farm operator families (#11). The Farmers Home Administration, in turn, receives its loanable funds either directly from government appropriations financed by tax revenues (#12) or from the issuance of debt in the bond markets (#13). Other items also flow through this and other selected linkages in figure 1. For example, flow #12 includes transfer payments and all government loans to businesses and consumers as well as government tax receipts, while flow #13 includes all government securities transactions.

What conclusions can we draw from these financial interfaces in the macroeconomy for the need to endogenize them in sector models capable of addressing the impact of alternative national economic policies? First, the level of private saving (both business and personal) directly affects the level of funds flowing to the bond and equity capital markets as well as to deposit-based financial intermediaries. Thus, a decrease in the rate at which capital gains income is taxed should increase the flow of private saving to equity capital markets, not only because private saving will have increased but also because savers will expect a higher after-tax rate of return on future investment in financial assets. It is difficult to say a priori whether this action will increase or decrease the flow of private saving to the bond markets, thereby affecting the supply of loanable funds to financial intermediaries. Expansionary monetary policies, such as an easing of reserve requirements, will increase the availability of loan funds at member banks and lower the cost of borrowing. Finally, the government sector, financial intermediaries, and large corporate businesses all compete for the private saving dollar in the bond and equity capital markets. A decrease in government sector borrowing in the bond market should increase the availability and lower the cost of outside financing to businesses and financial intermediaries.

Since the vast majority of annual farm business capital accumulation is not financed by corporations issuing securities in the bond and equity capital markets, why do we need to endogenize activity in this market if all we principally desire is to project the economic growth of the farm business sector? Part of the answer to this question should be obvious from the above discussion. First, the Farm Credit System and other money market lenders rely on this market for new loanable funds. In periods of tight money, therefore, the cost of loanable funds to these institutions will increase. Thus, even if we assume that these financial intermediaries are not crowded out of the bond market and can continue to obtain a volume of loanable funds sufficient to meet farm operator borrowing needs, aggregate investment theory suggests that an increase in the cost of capital finance will reduce the rate of further expansion of plant capacity. A less obvious but nonetheless important fact is that the farm business sector has a stake in nonfarm businesses acquiring sufficient external capital as well. For example, the cost and availability of external financing to nonfarm businesses will affect (*a*) the level of research and development expenditures and hence the future rate of capital-embodied technical progress in manufactured farm inputs; (*b*) the level of capital formation in nonfarm business assets, the expansion of existing plant capacity in the nonfarm business sector, and the cost and availability of manufactured farm inputs to farm businesses; (*c*) the demand for nonfarm labor, nonfarm wage rates, consumer disposable income, and the off-farm income of farm operator families; and (*d*) the prices received for raw agricultural products. Similarly, other changes in national economic policies, such as an increase in the investment tax credit rate which reduces the level of future tax payments, will also affect the level of activity in both the farm and nonfarm business sectors. If researchers projecting farm business outcomes under alternative national economic policies over a protracted period of time ignore the effects these changes have upon the rest of the economy, the projections of interest rates, input costs, and product prices used in their models will be in error. If the coefficients in annual projections models are not estimated using a simultaneous equations estimator, the projection will also suffer from simultaneous equations bias, although the resulting error likely will be much less than the specification error identified above. These errors, in turn, will affect the model's projections of (*a*) the stock of farmland and breeding livestock, (*b*) purchases of manufactured farm inputs, (*c*) crop and livestock output, and (*d*) net farm income and the real wealth position of farm operator families. Thus, endogenization of all the major interfaces between the farm business sector and the general economy is needed to assure capturing both the direct and indirect effects

of changes in national economic policies on the economic and financial performance of the farm business sector.

Previous Econometric Studies

Numerous econometric studies have focused on the investment demand for one or more categories of physical or financial assets held by farm-business sector participants. Other studies have focused on identifying the factors explaining the demand for and the supply of farm loan funds. Still others have estimated demand and supply relationships for either a single farm commodity or for a group of commodities. The empirical results reported by these studies provide a useful insight to the particular market in question. Given the limited scope of their studies, these researchers undoubtedly felt justified in ignoring the other interfaces with the general economy when estimating their models. Importantly, these models were not used to project the values of their dependent variable five to ten years into the future. Of interest to us here, however, are those studies that have attempted to project aggregate sector outcomes such as net farm income over time.

We can group previous sector projections models into three categories. The first category consists of aggregate product-market equilibrium models based upon a synthesized system of simultaneous equations which include an aggregate demand equation, supply equation, and market clearing equation. Such models endogenize only the domestic, raw agricultural product markets depicted in figure 1 when projecting farm-business-sector outcomes (Yeh; Quance and Tweeten). Often there is no statistical linkage in these models between those variables causing factor demand to change and the level of aggregate farm output. Instead, the aggregate supply curve is assumed to shift outward over time at a specific rate determined exogenously to the model. In the Yeh model, these shifts largely arise from productivity gains implied by research and education expenditures. What of annual transfers of farmland to nonagricultural uses and their effect on supply? What of annual farm business capital formation and how this capital flow is financed? Because of these and other omissions, this category of models is confronted by several seemingly knotty problems when projecting net farm income. Once the price of farm products and quantity are determined in the Yeh model, a set of synthesized equations and definitions is used to compute net farm income. Yet, the definition of net farm income requires an accounting of such farm production expenses as interest payments and capital consumption. Because Yeh has not projected annual investment and borrowing activities in the farm business sector, however, his projections of these expenses and net farm income are subject to question.[1] Finally, because these sector projection models lacks an interface with other markets in the macroeconomy or the financial decisions confronting the domestic consumer groups, they are ill-equipped to project the effects of alternative national economic policies, or other scenarios requiring an integrated multisector analysis, on the performance of the farm business sector and financial position of its participants.

The second category contains those sector models that have been linked to larger macroeconomic models through a set of identities (Chen, Roop and Zeitner). The Chen model, for example, uses a "micro-macro linkage block" to account for the interfaces between the farm business sector and the general economy. As Chen states, this "allows for testing the agricultural implications of macroforecasts and the macroimplications of agricultural forecasts" (p. 109). Thus, Chen's model and others like it would appear to meet more closely our informational needs. The interfaces between the farm business sector and the general economy illustrated in figure 1 should be captured by using functional relationships instead of a set of identities. Models of this type also do not contain equations explaining the level of farm business capital accumulation and capital finance. Hence, they too are ill-equipped to address questions regarding the direct and indirect effects of alternative national economic policies on the farm business sector. The criticisms made regarding the projections of farm production expenses by the Yeh model hold true here as well. Chen suggests that his model "shows promise for short-term forecasting and analysis" (p. 115). The absence of an accounting for changes in farm debt outstanding and the

---

[1] In fairness to Yeh, however, it should be noted that once the USDA's NIRAP system is completely estimated, many of the problems seen with the projections of net farm income in his model will be satisfied.

productive capital stock, however, precludes it from being used to make long-run projections.

The third category of sector models are those which either directly or indirectly account for the financing of farm business capital accumulation. Melichar and Baker both have estimated econometric sector models which determine residually the amount of external capital needed to finance projected annual capital accumulation by first subtracting the projected level of internal capital finance. Their models do not contain the rate of interest or other arguments normally included in the implicit rental price of capital. Furthermore, they use a trend relationship to project holdings of financial assets. Because of these and other properties, their models cannot reflect adequately the effects of alternative national economic policies on the farm business sector. Penson (1973) developed an aggregate income and wealth simulator which projects annual farm business capital accumulation and capital finance as part of a larger system of simultaneous equations. Because capital accumulation was determined in part by the expected after-tax rate of return, this model can examine the direct effects of changes in national economic policies. All of the models in this category, however, do not endogenize the interfaces between the farm business sector and the general economy. Omission of the indirect effects on changes in interest rates, prices paid for manufactured farm inputs, nonfarm wage rates, and the values of other exogenous variables in their models no doubt increase projection error. This is true now more than ever because of the present high use of manufactured farm inputs, external financing, and off-farm income earned by farm operator families.

Concluding Comments

McCracken, in reviewing the sluggish level of capital formation so far during the 1970s and the U.S. Treasury's diversion of private saving to financing budget deficits, concludes that restrained government outlays, coupled with an increase in investment tax credit and lower ordinary income tax rates, are needed. Others are calling for a reduction in the capital gains income tax rates to increase the amount of private saving flowing to equity capital markets. We must be prepared to quantify what the likely effects of such changes in tax policy will be on the farm business sector over time. Additional research is needed, therefore, to examine both the direct and indirect effects of national economic policy changes on farm-business capital formation as well as the cost and availability of capital finance.

King has cited the need to incorporate the effects of risk in sector econometric models. The hypothesis is that, by doing this, we will be able to project farm business outcomes with less error in periods of instability. Most risk studies to date have focused on farm level responses to risk in a production mode. How does farm operator behavior toward business and financial risk affect their investment and financing decisions? How do we cope with the aggregation bias associated with aggregate risk analyses in the farm business sector? Even if we can satisfactorily resolve these issues, we still must account for responses to risk in the general economy even though our primary concern is projecting the growth of the farm business sector. For example, interest rates on new loan funds may increase and their availability decline in periods of relatively high instability in the farm business sector as risk-averse lenders rearrange their portfolios in favor of those uses of funds with less risk per dollar of return. Expansion of plant capacity in the nonfarm business sector also may be slowed in response to increasing risk, thereby affecting the cost and availability of manufactured farm inputs, the level of consumer disposable income, farm product prices, and the availability of off-farm employment to farm operator families.

In conclusion, the incorporation of general economic outcomes in econometric projections models for the farm business sector requires endogenizing a variety of interfaces between this sector and the general economy. The task of endogenizing these linkages is great and the data are frequently a limiting resource. By better understanding their nature, however, we should be in a better position to reconcile why existing models miss the mark and identify where future data gathering efforts are needed.

References

Baker, Timothy G. "An Economic and Financial Projections Model for the U.S. Farming Sector." Ph.D. thesis, Michigan State University, 1978.

Chen; Dean T. "The Wharton Agricultural Model: Structure, Specification, and Some Simulation Results." *Amer. J. Agr. Econ*. 59(1977):106–16.

Fox, Karl A. *An Appraisal of Deficiencies in Food Price Forecasting for 1973 and Recommendations for Improvement*. Internal Report to the President's Council of Economic Advisors, Washington, D.C., Nov. 1973.

Johnson, Stanley R. "Agricultural Sector Models and Their Interface with the General Economy: Discussion." *Amer. J. Agr. Econ*. 59(1977):133–36.

Just, Richard E. "Agricultural Sector Models and Their Interface with the General Economy: Discussion." *Amer. J. Agr. Econ*. 59(1977):137–40.

King, Gordon A. "Econometric Models of the Agricultural Sector." *Amer. J. Agr. Econ*. 57(1975):164–71.

Melichar, Emanuel. "Aggregate Farm Capital and Credit Flows Since 1950 and Projections to 1980." *Agr. Finan. Rev*. 33(1972):1–7.

McCracken, Paul W. "The Nature of the Capital Problem in the Coming Decade." *What Will Tomorrow Cost? The Challenges of Capital Formation*. Chicago: Continental Bank, Nov. 1977.

Penson, John B., Jr. "An Aggregative Income and Wealth Simulator for the U.S. Farm Sector: Its Description and Application to Policy Analysis." Ph.D. thesis, University of Illinois, 1973.

———. "Toward an Aggregative Measure of Saving and Capital Finance." *Amer. J. Agr. Econ*. 59(1977): 49–60.

Popkin, Joel. "Some Avenues for the Improvement of Price Forecasts Generated by Macroeconomic Models." *Amer. J. Agr. Econ*. 57(1975):157–63.

Quance, Leroy, and Luther Tweeten. "Excess Capacity and Adjustment Potential in U.S. Agriculture." *Agr. Econ. Res*. 24(1972):57–66.

Roop, Joseph M., and Randolph H. Zeitner. "Agricultural Activity and the General Economy: Some Macromodel Experiments." *Amer. J. Agr. Econ*. 59(1977):117–25.

Schuh, G. Edward. "The New Macroeconomics of Agriculture." *Amer. J. Agr. Econ*. 58(1976):802–11.

Yeh, Chung J. "Prices, Farm Outputs, and Income Projections under Alternative Assumed Demand and Supply Conditions." *Amer. J. Agr. Econ*. 58(1976): 703–11.

Application of Portfolio Theory to Farmer and Lender Behavior

Lindon J. Robison and John R. Brake

Randomness of commodity output and prices in agriculture are well-known phenomena that have plagued both farmers and their lenders as they develop plans and financial programs for the coming year. The same phenomena have plagued researchers who attempt to model the farmer-lender relationships for improved explanations of farmer and lender behavior. Early decision models of resource allocation under risk sought to maximize expected returns. However, in the early 1700s, Bernoulli demonstrated the irrationality of this criterion in explaining gambling behavior. More recently, portfolio theory, as developed by Markowitz and Tobin with extensions by Sharpe and Lintner, has improved our ability to analyze farmer and lender behavior under risk by considering variance as well as the expected value of returns.

This paper discusses developments in portfolio theory, reviews its application to farmer and lender behavior, considers its limitations, and suggests several extensions to account for asset liquidity, liquidity risk, and portfolio adjustments. We conclude with recommendations for future application of portfolio theory to farmer and lender behavior.

Developments in Portfolio Theory

What is portfolio theory? Like such terms as risk and love, it is a word many seem to know, but few have defined. So, we will supply a definition of our own: portfolio theory is an efficiency criterion that identifies a set of investment plans that minimize variance (maximize expected returns) for given levels of expected wealth (variance), from which well-defined classes of decision makers can find their expected utility-maximizing solution. This set of investment plans, often referred to as the expected value-variance (EV) set, is efficient because it restricts the search for preferred solutions to those EV efficient plans.

Lindon J. Robison is an assistant professor and John R. Brake is a professor of agricultural economics at Michigan State University.

Michigan State Agricultural Experiment Station Journal Article No. 8770.

The authors are grateful to Peter J. Barry for valuable comments on an earlier draft of this article.

Limitations of Portfolio Theory

A limitation of portfolio theory is that not all decision makers can find their preferred plan in the EV set. Tobin showed the EV set to be efficient for investors with quadratic utility functions; others showed it to be efficient for risk-averse investors only if the outcomes from investment plans were normally distributed (Borch, Feldstein, and Samuelson). For other classes of investors and probability distributions, it does not necessarily include the preferred plan. Moreover, when the EV set is obtained using quadratic-programming methods, portfolio theory imposes additional limitations. Investment activities are required to be completely divisible, nonnegative, and linear (i.e., outputs are linear combinations of the inputs). And, in most cases, portfolio theory only considers price risk.

There are at least two reasons why an expected return-variance criterion is important today: (*a*) the difficulty of making decisions under uncertainty, and (*b*) the simplified way in which portfolio theory identifies efficient investment plans. Under certainty, finding the preferred plan is simple. Each plan has a single outcome; so, as long as decision makers prefer more to less, they prefer the profit-maximizing plan. But under uncertainty, each investment plan has many possible outcomes which should be considered. Hence, an index is needed to rank investment plans according to the expected value of each investor's utility function. But finding the expected utility of many feasible plans can be a laborious task. As a result, any efficiency criterion which re-

duces the choice set without requiring the investor's utility function, is an important aid in making decisions under uncertainty.

Portfolio theory not only reduces the choice set, but does so in a simplified manner. Consider the alternative efficiency criteria of stochastic dominance. These criteria require the pairwise comparison of existing investment plans. The EV set, on the other hand, can be obtained using quadratic programming methods which construct and identify efficient investment plans. Hence, portfolio theory has remained popular despite the development of other criteria that are efficient under more general conditions.

Portfolio Theory and Its Application in Agricultural Economics

Portfolio theory originally was developed to answer such financial questions as why investors diversify their portfolios of financial assets, why they hold cash balances, and how capital asset prices are determined. Portfolio theory is now experiencing wider application including use in studies of resource allocation, growth, and financing in agriculture.

But something like portfolio theory was also being suggested by Heady in agricultural economics at about the same time it was being discovered in finance theory. He discussed mean-variance relationships and the importance of diversification to reduce variance. Later, Freund determined the unique solution to a farm diversification problem by maximizing the expected value of a negative exponential utility function that turned out to be a member of the EV set. Much later, Heifner applied portfolio theory to a grain inventory problem while S. R. Johnson applied it, along with Tobin's separation property, to the problem of farm diversification. Still, the applications of portfolio theory lagged while linear programming, along with the expected returns rule, remained popular. This prompted Stovall to remind us of that rule's inadequacy and to recommend portfolio theory and quadratic programming as an alternative.

One explanation of portfolio theory's slow acceptance was the lack of computational capacity of available quadratic programming algorithms which could be used to derive the EV set. Researchers found the size of problems that could be included in quadratic programs was limited, especially when compared to those that could be solved using linear programming. As a result, attention was diverted to finding linear alternatives. In finance, Sharpe's single index model appeared to be an acceptable alternative. In agricultural economics, separable programming (Thomas et al.), Hazell's MOTAD (minimization of the absolute deviations), and Chen and Baker's two-stage marginal risk constraint program were developed. Quadratic programs existed, however, and some have found them to be adequate (Cutler and Pass).

More recently, agricultural economists have applied portfolio theory to an increasing number of diverse problems. Scott and Baker applied portfolio theory to an Illinois corn and soybean farm, adding Baumol's EL or safety-first criterion. Still other applications were by Barry and Willmann to contracting problems with credit constraints, by Whitson, Barry, and Lacewell to a vertical integration in ranch management, and by Buccola and French to deciding on tomato contracting alternatives, and the list goes on.

Despite the diversity of questions, the results of these applications all had a familiar ring. As solutions progressed from lower to higher expected wealth portfolios, investors were required to invest in riskier prospects, hardly a surprising result. But for a while, just being able to identify the set of EV efficient choices seemed enough to ask of portfolio theory. A later study by Robison and Barry approached the problem differently. It analyzed how the equilibrium solutions on shifting EV frontiers would change for well-defined classes of decision makers. This equilibrium adjustment study followed traditional economic theory in defining income and substitution effects as well as decision makers' response to changes in risk-free wealth and changes in probability distributions.

Initially, portfolio theory required that outcomes be distributed normally or that investors maximize the expected value of quadratic utility functions. However, when solved using quadratic programming, activities were required to be completely divisible, nonnegative, and linear, i.e., outputs are linear combinations of the inputs. And, in most models, portfolio theory only considers price risk.

Most physical production processes, however, are not linear; asset choices are not always completely divisible; output is rarely certain. Yet, to allow for nonlinear production functions, indivisible asset choices, or

stochastic output separate from stochastic prices are problems not amenable to risk programming. How serious are these limitations of portfolio theory? It is paradoxical that the normality assumption for which portfolio theory is most often criticized appears to be the least objectionable. More objectionable are the linearity assumption and the exclusion of output risk. Output variability seems at least as important as price variability and is less easily managed. In addition, assuming asset choices are completely divisible is often violated in real-world farm planning.

These same criticisms do not apply to financial applications of portfolio theory. When building investment plans of financial assets, choices are characterized by linear, certain production functions, and only price risk is important. Moreover, financial assets are more divisible. Hence, we conclude that as an empirical tool, portfolio theory can be applied correctly and usefully to financial allocation problems. It appears less appropriate as a farm planning and decision-making tool where nonlinear physical processes characterize farm firms' environment. As a result, we expect to see more flexible empirical tools replace traditional portfolio models, such as Monte Carlo programming techniques which allow for nonlinear production functions, indivisible asset choices, and variability in output as well as prices (Anderson).

Extensions of Portfolio Theory

Decision makers begin any decision period with most of their funds already allocated. Moreover, altering their existing portfolio by disinvesting and reinvesting is seldom a costless activity, except in those rare cases when assets are perfectly liquid. Recognizing the cost of adjustment and that investors begin with resource allocations already made can improve portfolio theory's usefulness as both an empirical and theoretical tool.

Two related notions from agricultural production and finance theory can help extend portfolio theory's usefulness. The two concepts are asset fixity and asset illiquidity. According to Hicks, liquidity is a Keynesian word and the "reason why money commands a premium over bills or bonds" (p. 789). Hence, investors must be compensated for holding illiquid assets. According to Keynes, liquid investments are more "realizable at short notice without loss" (p. 789). That is, the difference between the price received from selling a liquid asset compared to the price paid for the asset is small. This interpretation of Keynes' definition is complicated by time considerations. For, as Pierce describes it, the sale or salvage value of an asset increases with the time available to transact the sale. But for our static model, Modigliani's definition seems adequate, i.e., an asset is liquid if an individual's decision to buy or sell it does not affect the price finitely. Illiquid assets, in contrast, are priced differently, depending on whether one is buying or selling.

Asset liquidity becomes important for farmers who face either stochastic cash demands or certain cash demands but uncertain income streams. Consider the farmer facing fixed cash obligations on a land purchase contract, machinery payments, and family living expenses. In addition, he may also need liquid assets to meet unforeseen expenditures such as machinery repairs, illness, or vacations. Now assume these cash commitments are to be met with farm earnings, which, in turn, depend on weather, exports, sales, etc. If these cash receipts do not cover his cash needs, the borrower must then rely on cash reserves or credit, or he must liquidate some assets. A prudent manager will plan for such an event by retaining sufficient unused credit and liquid assets to accommodate random cash receipts and needs.

Asset flexibility may be desirable for another reason. Suppose economic conditions change, making formerly profitable enterprises unprofitable or less profitable than new ones. If assets are characterized by such high liquidation costs that these offset any possible gains from new investments, then no changes in the firm organization will occur. But portfolio applications that ignore the cost of portfolio adjustments will likely show greater responsiveness to changes in returns and variances than actually occur because of liquidation costs.

Perhaps the omission of liquidity considerations may account for a rather strange preoccupation our profession has with safety-first criteria (Webster and Kennedy). Safety-first plans usually exclude portfolio plans that have some probability greater than some specified minimum that a disaster level of income may occur. Obviously, one cost of not meeting minimum cash flow requirements is liquidation costs. Safety first criteria may

account for these costs implicitly by excluding plans which may, with some specified probability, require liquidation. The disadvantage, however, is that while an efficient set is derived, the question of efficient for whom is not answered. And to argue that it is efficient for those investors with a safety-first criterion is to rely on a tautology.

Now consider the related idea of asset fixity. Johnson and Hardin define an asset to be fixed when its marginal value product is bounded by acquisition and salvage prices. Hence, firms have no incentive to modify their holding of fixed assets. But the difference between acquisition (purchase) and salvage (selling) prices identified illiquid assets according to our earlier definition. As a result, illiquid assets are more likely also to be fixed.

These two features, asset illiquidity or asset fixity, can easily be incorporated into a portfolio model to capture more explicitly the crucial elements of farm level decisions. We begin with the standard portfolio model consisting of n production activities whose distributions of returns are normal with expected returns equal to r_i and covariances and variances equal to $\sigma_{ij}(i, j = 1, \ldots, n-1)$ where $\sigma_{nn} = 0$. We maximize the following:

$$(1) \quad L = \sum_i (1 + r_i)\, X_i - (\lambda/2) \sum_i \sum_j \sigma_{ij} X_i X_j,$$

subject to $W_o = \sum_i X_i$ and $X_i \geq 0$, where $i, j = 1, \ldots, n$.

To include the effects of asset illiquidity, we identify asset holdings of decision makers at the end of the previous period as $X_{1_0}, \ldots, X_{n_0}$ and associate with each asset a liquidation cost c_i $(i = 1, \ldots, n)$. That is, X_i and $(1 - c_i)$ X_{i_0} equal acquisition and salvage prices of the ith asset. The modified portfolio problem now begins with an existing portfolio of liquid and illiquid (or fixed) assets. The decision maker then has two mutually exclusive choices regarding each asset: to invest (X_i) or to disinvest (Z_i). If he disinvests, the asset's salvage value $(1 - c_i) Z_i$ can be reinvested in asset X_j or held as a cash reserve. Also available for investing are increases in net worth (ΔW_o), earned in the previous period. As a result of investing and disinvesting activity, the expected net worth W is

$$(2) \quad W = \sum_{i=1}^{n} (1 + r_i)(X_i + X_{i_0} - Z_i),$$

where $\sum_i X_i = \Delta W_o + \sum_i (1 - c_i) Z_i$, $X_i Z_i = 0$, $\leq Z_i \leq X_{i_0}$, and Z_i, $X_i \geq 0$. The portfolio variance σ^2 is

$$(3) \quad \sigma^2 = \sum_i \sum_j (X_i + X_{i_0} - Z_i)(X_j - X_{j_0} - Z_j)\sigma_{ij}.$$

The result of including asset liquidity considerations in the portfolio problem is to reduce investments in response to changes in possible returns on assets. As a result, portfolio revisions will be reduced. The smaller increase in an asset in response to improved investment opportunities occurs because disinvesting in the other assets, if required, incurs a liquidation cost. Moreover, the increased return from moving funds from the one asset to another asset must not only cover the liquidation cost but also must increase expected marginal utility above that offered by the competing asset. Hence, with consideration given to asset illiquidity, the portfolio model may show only modest portfolio adjustments even with substantial changes in investment opportunities.

The portfolio model described thus far accounts for portfolio revision costs incurred because assets are illiquid. We extend the model now to include one other consideration for portfolio revision: meeting stochastic cash demands. A portfolio model has been described which includes in the variance-covariance matrix a consideration of positive covariance between cash demanded and returns earned (Chen, Jen, and Zionts). Obviously, if cash demands are to be met from portfolio returns, there is some "liquidity risk" preference for holding assets whose returns are positively correlated with cash demands. As a result, returns are high when cash demands are high.

To model this liquidity risk feature, we include in the revised portfolio model a new random variable v, which represents random cash demands of the firm. This stochastic demand is accounted for by subtracting its expected value $\bar{v}$ from expected wealth and adding the covariance of returns and cash demands $(\sum_i X_i \sigma_{vi})$ to portfolio variance. Now we can express the standard portfolio model,

$$(4) \quad \sum_i (1 + r_i) X_i - \bar{v} - \lambda/2\Big[\sum_i \sum_j X_i X_j \sigma_{ij} - \sum_i X_i \sigma_{vi}\Big].$$

Finally, consider extending portfolio theory to account for the interaction between borrowers and their lenders in determining opti-

mal portfolios. How much credit a borrower has is determined by his lender, but the borrower influences his lender's credit assessment by his choice of investments. If a borrower's net worth is tied up in oil exploration equipment, for example, his lender likely will extend him less credit than if his wealth is invested in savings certificates at the local bank. What the borrower sacrifices for his greater credit generating investment plan is a lower expected return. The differential in credit evaluation of lenders in response to different strategies already has been explored by Barry and Willmann. We show how portfolio theory can incorporate these effects.

To simplify notation, we ignore liquidity and liquidity risk considerations and consider a two-phased investment decision facing the borrower: How should one invest to generate an optimal amount of credit with acceptable returns, and how should he invest the borrowed funds in a way that efficiently uses the credit generated from the first phase of the investment plan? The portfolio model is similar to the one described earlier, except that there are twice as many investment choices: n investment opportunities for initial wealth denoted $X_1, \ldots, X_n$ and n investment choices for allocation of the borrowed funds denoted $X^*_1, \ldots, X^*_n$.

When the lender evaluates the credit worthiness of the borrower, this allocation of his own wealth determines the amount of loan funds the borrower will receive. It appears that credit evaluation is one of the most important ways lenders differentiate between borrowers (U.S. Department of Agriculture).

Assume the lender assigns to each dollar of equity invested in the ith activity a credit coefficient α_i, that is, a dollar of equity invested in the ith activity generates credit equal to α_i. The total borrowing capacity can then be expressed as

$$B = \sum_{i=1}^{m} \alpha_i X_i. \tag{5}$$

Meanwhile, the borrower's allocation of borrowed funds determines the rate of credit depletion. Risky, illiquid activities likely will use credit faster than safe, liquid activities. Hence, a credit depletion coefficient β_i is assigned to investments $X^*_1, \ldots, X^*_n$ which use borrowed funds. Credit used, of course, must not exceed credit generated.

$$\sum_i \alpha_i X_i \geq \sum_i \beta_i X^*_i. \tag{6}$$

Finally, subtracting the cost r_B of credit from the return on activities which use credit, our extended portfolio model becomes

$$\sum_i r_i X_i + \sum_i (r_i - r_B) X^*_i - \lambda/2 \left[\sum_i \sum_j (X_i + X^*_i)(X_j + X^*_j)\, \sigma_{ij}\right]. \tag{7}$$

The credit-generated coefficients now play important roles in determining the optimal allocation of resources and models the interrelationships between borrowers and lenders. The values and parameters that determine these coefficients merit close examination. Obviously, the riskiness and liquidity of assets are important. Lenders prefer safe liquid assets to the extent possible because their returns from loans are fixed and do not depend on the profit earned by the borrower. As a result, they do not share in unusually favorable returns, although they may share in the cost of disastrous returns if refinancing is required when funds available to the lender are tight or if foreclosure or other equity recovery strategies are required.

The major value of unused credit is to meet stochastic cash demands. As a practical matter, stochastic cash needs can also be met by liquidating assets. And if the cost of liquidating assets is small, the value of unused credit is lessened. But often liquidating assets to meet stochastic cash needs is costly and may disrupt the farm organization and reduce its efficiency. Hence, it is an important choice variable for borrowers as they determine their optimal allocation of resources.

Unfortunately, we see no easy extension of portfolio theory that would allow it to determine the optimal use of credit, at least using conventional programming techniques. The value of credit cannot be determined until all other choice variables in the investment plan have been determined. In effect, the value of credit is a cost savings variable depending on the value of the random cash demand, the stochastic returns earned on investments, and the values of the choice variables. It can, however, be determined in an *ex post* fashion by calculating the differences in expected return from an optimal plan with no unused credit versus plans with various levels of unused credit. This valuation procedure requires solution procedures such as Monte Carlo or other nonlinear search methods not usually applied to portfolio problems.

An alternative to determining the optimal amount of unused credit could be found by

including a chance constraint in the standard portfolio model. One might require that expected returns plus unused credit exceed the expected value of cash demands by some probability to be determined by the borrower. This is a standard chance constraint problem and is incorporated easily if we know the probability with which income and unused credit should exceed the expected value of cash demands. Since this probability is hardly ever known, the value of this solution procedure is reduced.

Conclusions and Recommendations

This paper reviewed the development of portfolio theory and its later use as a farm-planning model under uncertainty. As a financial model, the assumptions and restrictions seem acceptable: production is linear, asset choices are mostly divisible, and the variance is on the price side. But as a farm-planning tool, portfolio models seem less useful because production is not linear, asset choices are seldom completely divisible, and variance on the output side is at least as important as variance on the price side. Still, as an empirical tool, it represents an improvement over previously popular linear programming models.

This paper also reviewed briefly several applications of portfolio theory in agricultural economics. They tended to describe portfolio choices along EV frontiers and allowed costless transition from one portfolio to another and from one asset to another. We argue this simplification ignores an essential consideration of the investment decision: asset illiquidity (liquidity) and asset fixity. The two notions are similar and when their effects are included in a portfolio model, they significantly reduce the economic incentives for portfolio revisions. Other extensions to portfolio theory which we recommended were (*a*) including the value of stochastic returns in meeting stochastic cash needs (liquidity risk considerations), and (*b*) accounting for the value of firm wealth in generating credit and including as a cost, the rate at which activities use credit. Finally, we observed that unused credit was valuable to a firm, but we found no easy way to determine its value or optimal use, at least within the context of the standard portfolio model.

References

Anderson, J. R. "Programming for Efficient Farm Planning Against Non-Normal Risk." *Aust. J. Agr. Econ.* 19(1975):94–107.

Barry, P. J., and D. R. Willmann. "A Risk Programming Analysis of Forward Contracting with Credit Constraints." *Amer. J. Agr. Econ.* 58(1976):62–70.

Borch, K. "A Note on Uncertainty and Indifference Curves." *Rev. Econ. Stud.* 36(1969):1–4.

Buccola, S. T., and B. C. French. "An Analysis of Pricing Alternatives for Long-Term Marketing Contracts." *S. J. Agr. Econ.* 9(1977):17–23.

Chen, A. H. Y., F. C. Jen, and S. Zionts. "The Joint Determination of Portfolio and Transaction Demand for Money." *J. Finance* 29(1974):175–84.

———. "Portfolio Models With Stochastic Cash Demands." *Mgmt. Sci.* 19(1972):319–32.

Chen, J. T., and C. B. Baker. "Marginal Risk Constraint Linear Program for Activity Analysis." *Amer. J. Agr. Econ.* 56(1974):622–27.

Cutler, L., and D. S. Pass. *A Computer Program for Quadratic Mathematical Models to be Used for Aircraft Design and Other Applications Involving Linear Constraints.* Santa Monica, Calif.: Rand Corporation, 1971.

Feldstein, M. S. "Mean-Variance Analysis in the Theory of Liquidity Preference and Portfolio Selection." *Rev. Econ. Stud.* 39(1969):5–12.

Freund, R. J. "Introduction of Risk Into a Risk Programming Model." *Econometrica* 24(1956):253–63.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semi-Variance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1971): 53–62.

Heady, E. O. "Diversification in Resource Allocation and Minimization of Income Variability." *J. Farm Econ.* 34(1952):482–96.

Heifner, Richard G. "Determining Efficient Seasonal Grain Inventories: An Application of Quadratic Programming." *J. Farm Econ.* 48(1966):648–63.

Hicks, J. R. "Liquidity." *Econ. J.* 72(1962):787–802.

Johnson, G. L., and L. S. Hardin. *Economics of Forage Valuation.* Purdue University Agr. Exp. Sta., Bull. 623, Apr. 1955.

Johnson, S. R. "A Re-examination of the Farm Diversification Problem." *J. Farm Econ.* 49(1967):610–21.

Lintner, J. "Security Prices, Risk, and Maximum Gains From Diversification." *J. Finance* 21(1965):587–615.

Markowitz, H. "Portfolio Selection." *J. Finance* 7(1952):77–91.

Modigliani, F. "Liquidity Preference and the Theory of Interest and Money." *Econometrica* 12(1944):45–88.

Pierce, J. L. "Commercial Bank Liquidity." *Federal Reserve Bull.* 52(1966):1093–1103.

Robison, L. J., and P. J. Barry. "Portfolio Adjustments: An Application to Rural Banking." *Amer. J. Agr. Econ.* 59(1977):311–20.

Samuelson, Paul A. "The Fundamental Approximation Theorem of Portfolio Analysis in Terms of Means,

Variances, and Higher Moments." *Rev. Econ. Stud.* 37(1970):537–42.

Scott, J. T., and C. B. Baker. "A Practical Way to Select a Farm Plan Order Risk." *Amer. J. Agr. Econ.* 54(1972):657–60.

Sharpe, W. *Portfolio Theory and Capital Markets*. New York: McGraw-Hill Book Co., 1970.

Stovall, J. "Income Variation and Selection of Enterprises." *Amer. J. Agr. Econ.* 48(1966):1575–79.

Thomas, W., L. Blakeslee, L. Rogers, and N. Whittlesey. "Separable Programming for Considering Risk in Farm Planning." *Amer. J. Agr. Econ.* 54(1972):260–66.

Tobin, J. "Liquidity Preference as Behavior toward Risk." *Rev. Econ. Stud.* 25(1958):65–86.

U.S. Department of Agriculture. *Agricultural Finance Outlook*. ERS AFO-16.

Webster, J. P. G., and J. O. S. Kennedy. "Measuring Farmers' Trade-Offs between Expected Income and Focus Loss Income." *Amer. J. Agr. Econ.* 57(1975):97–105.

Whitson, R. E., P. J. Barry, and R. D. Lacewell. "Vertical Integration for Risk Management: An Application to a Cattle Ranch." *S. J. Agr. Econ.* 8(1976):45–50.

Discussion

Marvin Duncan

The authors of these papers have recognized correctly that the U.S. agriculture sector now interacts with an international economy and that innovations with respect to capital flows and intermediation affect U.S. agriculture more frequently than before, but in ways that are still poorly understood. The models show promise for explaining economic phenomena and the implications thereof in ways that are useful to public and private decision processes. This is important. Too often economists move on to new research before developing the interface with those who make economic decisions.

The models presented also share a prodigious demand for data, some of which are unavailable, except by survey. Despite efforts nationally to improve data sources and quality, a countervailing effort to reduce the reporting burden of financial institutions likely will mitigate efforts to have some of the needed data collected by government bodies. This is not a criticism of the authors. It is entirely correct to build conceptual models, selecting variables for inclusion on the basis of theoretical rigor. But, making such models operational frequently requires compromises.

Finally, these are conceptual models. In the first two papers, it would have been useful to see more meat on the conceptual bones. Questions as to how the relationships indicated are to be specified and estimated and the performance of the models outside the data periods used for estimation must remain unanswered for now. Consequently, agricultural economists will benefit from progress reports on these models.

Modeling Flow of Funds

The Boehlje, Harris, and Hoskins paper proposes using a spatial allocation model to examine the flow of funds in localized financial markets. This is particularly timely, as productive agriculture uses ever greater amounts of borrowed capital—often more than can be generated within a local market area—and the financial industry is adopting new technology to expedite fund intermediation (such as electronic fund transfers).

The model, when operational, could be used *ex ante* to determine the implications of a number of policy questions presently being debated in the finance industry—loan packaging, usury limits, and branch banking questions, to name a few. However, to be of maximum value, a model ultimately should be generalized to include most, if not all, nongovernment-held credit institutions within a study area. Specifically, it seems useful to consider including Farm Credit System outlets as well as commercial banks. This will require some reformulation of the model but may be worth the effort.

Some potential problems in specifying the model and making it operational seem likely. The first is the market-delineation procedure. I am not convinced that response times between price adjustments—interest rates on loans or time deposits—is an adequate criterion by itself to define a market area. Other measures may be necessary, as well; for example, newspaper or television station coverage. If price adjustments are used, interest rates may not be the most sensitive measure. Charges for other bank services or interest rates on consumer loans may be more useful, exhibiting greater variance. A good deal of survey work would be required to generate an individual institution's interest rate series. Even then, banks may not be able to generate such an historical series, or may regard such information as proprietary. Finally, it is unlikely that such a data series, except for a sample of the institutions, will be requested by bank or farm credit regulatory agencies.

The variables to be included in the supply and demand equations seem appropriate as a first approximation. I am less confident of the use of cross-sectional data to fit the equations.

Marvin Duncan is an agricultural economist with the Federal Reserve Bank of Kansas City, Missouri.

Time-series data might yield more stable coefficients. Correctly specifying transactions costs and management constraints poses special difficulties, yet is essential for the model. Federal Reserve System functional cost data and data collected for regulatory purposes will be useful sources. Testing the model with different management assumptions based on survey data would be useful.

Finally, the authors recognize the need to modify the spatial allocation model to permit varying degrees of monopoly and disequilibrium in the markets. Perhaps the model should be modified further to recognize growth or loan maximizing behavior subject to certain risk constraints.

Incorporating General Economic Outcomes in Agriculture Models

The attention to linkages between the farm business sector and the general economy in the Penson and Hughes paper is welcome. The financial interfaces outlined in the model, and the supporting rationale, answer many of the major shortcomings of previous models. While the authors have developed a research framework, it would have been useful to have more detailed discussion of the form their efforts to endogenize sector interfaces would take. However, their discussion of shortcomings in previous models does give some implicit indication of their intent.

Most large-scale agriculture sector and macro models presently require difficult judgment calls on establishing values for exogenous variables, and these are likely sources of error in model projections. Nonetheless, when considering much greater use of functional linkages, it is useful to remember that misspecification of the functional relationships or estimation with inadequate data series can also introduce error into model projections. The authors may be proposing to replace more identities with functional relationships in their model than is necessary to achieve improved sensitivity to economic shocks and greater projection accuracy.

The authors suggest their model is well equipped to project the effects over time of alternative national economic policies on the agricultural sector, as a result of more sophisticated functional linkages. Some unresolved questions still exist with respect to model performance, however. For example, the need to incorporate risk considerations is noted, but the paper does not indicate how this will be accomplished. Also, the authors have not yet determined the stability over time of the proposed supply and demand functions.

Portfolio Theory and Farmer-Lender Behavior

The Robison and Brake paper is a useful one, because firm level research frequently identifies basic economic relationships. Their summary of the evolution of portfolio theory and its application to agriculture, as well as their extension of the basic model, enhances the usefulness of portfolio theory as a tool to examine farm firm financial decision making.

Some problems in using the extended model are unresolved, however. Quantifying liquidation costs consistently and correctly presents an interesting problem. The question of how to handle liquidity risk is a difficult one, as well. It does seem more acceptable to weight such risk differently than the weight assigned to variance of returns. It is a different kind of risk and should be handled as such.

The limitations inherent in even the extended utility function outlined in the paper must be recognized. The slow adjustment the authors note to changing profitability exhibited by most farm firms is probably due not only to resource fixity and liquidation costs. I suspect a good deal is due to habit and to the personal preferences of farm managers. For example, why have not recent profits in hog production resulted in more new entrants and greater output from present producers? Part of the answer is related to fixity and liquidation costs. But part of the answer is tied to labor-leisure choices by farmers, as well.

Farm firm level decision making continues to be a productive research focus. Increasingly, entrepreneurs are looking for new ways to access production resources and for optimal firm growth strategies. Research in support of these goals will find a ready audience. It remains to be seen whether portfolio theory—with extensions—will find the practical acceptance the authors contend it deserves.

Discussion

William McD. Herr

In the concluding section of their literature review of "Agricultural Finance and Capital Markets," Brake and Melichar offer suggestions for future research: "Currently, theoretical and modeling efforts would seem to have particular potential in work on capital formation, decision theory under risk and uncertainty, sources and uses of funds, capital markets, and firm growth." (p. 474)

The three papers not only meet this challenge, but, in my view, attempt to extend knowledge frontiers in critical and important areas of agricultural finance. As the content of the papers ranges from micro to macro, I choose to discuss them in that order.

Robison and Brake question the accuracy of portfolio models as a farm-planning tool, but argue they are more acceptable when used as a financial model. Their literature review of portfolio theory, suggested developments and applications are useful and I believe the profession is indebted to them for their discussion. They recommend the inclusion of financial components, such as liquidity considerations, as a way to improve our ability to describe farm behavior. This recommendation, though useful, leaves this discussant unsatisfied.

If we are to understand farm behavior, the inclusion of financial components in our models is necessary, but the authors do not specify these components other than liquidity considerations and perhaps credit reserves. Discussions regarding asset holdings, income, and its variability are dependent upon a large and varied assortment of inventory, debt, marketing, insurance, transaction requirements, and risk management strategies, all of which somehow must be modeled.

But even if our models included more of the economic environment within which decisions are made, it is my impression that we still have all too little knowledge concerning the income-variance attitudes of farm operators. Thus, while the procedure can show that a given set of resources can be allocated in such a way as to give a variety of points on an EV frontier, it is not entirely clear whether a segment or the entire frontier is relevant. Without this knowledge, we can say only that differences in resource combinations can affect farmer behavior, but we are left uncomfortable by not knowing how much it actually affects farm decision making. Thus, I make a modest plea for some continued effort to expand our knowledge concerning the nature of risk preferences of managers.

Finally, I note that the authors do not expound on the implications of portfolio theory to lender behavior. It would be interesting to have their views concerning what part of a bank's assets and liabilities are illiquid and respond sluggishly to outside stimuli. What portions can be adjusted? And what effect do these have on availability and terms of credit to the farm sector? There is some evidence that rural bankers view farm loans as being of higher quality (lower risk) than other business loans (ABA, p. 3). If true, in times of tight credit, the farm sector may not be as severely rationed as other sectors of the rural economy.

These comments lead us directly to the Boehlje, Harris, and Hoskins paper. This paper focuses on a problem of current concern to country banks, bank authorities, and the rural sector. The flow of funds within and between local areas is not understood, and it is proposed that a spatial model may provide some useful insights.

One question this discussant considered was whether the characteristics of this commodity pose any special problem for a spatial model. My conclusion is that conceptually, probably not, but operationally the model becomes considerably more complex. In this regard, it would help to have their definition of funds, whether they are concerned with gross or net flows, and the time frame of their model. Perhaps an even more basic concern is that other commodities have a beginning (producer) and a final destination (user) while

William McD. Herr is a professor, Department of Agribusiness Economics, Southern Illinois University-Carbondale.

funds tend to flow around a circuit. Because of this circuity, demand and supply functions and, hence, markets probably are not as easily defined as for physical commodities. Factors determining the production function for banks might include whether they are state or federally chartered, members of branch, chain, or unit bank systems, as well as other factors. In any event, the production function of banks and, hence, supply equation, differs among banks, and between banks and other financial institutions and, therefore, should also be included in any area model.

Similarly, the products and services that financial institutions provide are demanded by a clientele that may have local dimensions (personal loans) or regional or even national dimensions (selling of federal funds). Thus, any given institution likely would be part of many different product markets which are interrelated. Moreover, the products of these markets are packaged and priced in a variety of ways. While the author's delineation of local markets conceptually allows for this, based on the previous line of reasoning, I submit this is operationally difficult. Perhaps a clearer perception of the flow of funds in a local area would be to concern ourselves less with the area in a geographic sense and strengthen knowledge of demand and supply functions which impact on the "rest-of-the-world."

Essentially the heart of the flow of funds model in a local area revolves around the demand and supply equations. Before we can obtain much insight from the proposed model, we must know more about the nature of the production functions of financial institutions and the demand functions for their products and services.

Penson and Hughes indicate that their global model (farm-nonfarm and the rest of the world) focuses primarily on the linkage between private savings and the financing of farm business operating expenses and capital accumulation. In appraising their model, it seems appropriate to ask two related questions: Does the model capture the important financial relationships? Is the model being designed to provide answers to important public policy questions involving financial variables?

My answer to the first question is a qualified yes. The discussion and interrelationship shown in their figure 1 indicate major financial flows, but it is not clear that they have adequately modeled each sector. For example, the government sector is more complex than simply including FmHA. Allowance should be made for the activity of the Commodity Credit Corporation and the Small Business Administration. Government transfer payments to the farm business sector should also be considered explicitly. The flow of funds from this source apparently played an important part in easing financial stress in the latter part of 1977 and early 1978. And, it would seem that surpluses and deficits of the government sector as they impinge on the capital and credit markets also should be included. Thus, when the authors trace through the effects of a decrease in the rate of capital gains tax, they correctly conclude that the action should increase the flow of private savings to equity markets, but they fail to note the accompanying effect of the change in government receipts on financial markets.

In order to capture important financial relationships, it is probably necessary to include in econometric models risk and uncertainty considerations. However, it is only in the concluding section of their paper that the authors discuss this topic. As I read various commentaries concerning the present economic scene, nearly all couch some portion of their analysis on considerations of risk and uncertainty. How to incorporate risk into macro models, I for one do not know, but I cannot help wonder whether construction of models may have outrun our theoretical understanding of the economy that we are modeling.

The second question asked about the model is whether it can provide answers to important policy questions. Judging from the kinds of public policy issues discussed by the authors, my answer is yes. However, in the absence of equations one cannot be sure that the answers to the policy questions are any better than might be obtained from a different model. Thus while I am impressed with the purpose and objectives, the real tests of the model are the equations that link the various sectors. As the impacts the authors see occurring from these interfaces virtually ignore some important relationships, it seems appropriate to question whether these linkages are adequately portrayed.

In conclusion, we should be encouraged by these efforts to model the interrelationships between farm finance and other financial markets. For these more general macroeconomic models, not only are the specifications and data requirements complex and demanding,

but just keeping such models updated so as to provide input for policy makers is costly and time consuming.

In reviewing recent trends in the agricultural economics profession, Martin as well as others (e.g., Schuh) have argued that the profession has made little recent progress in the development of innovative analytical techniques in the macroeconomics area. Whether these models represent yet another point on this plateau or whether they will represent another upward thrust remains to be seen. In my judgment, the focal point provided by finance might just provide a needed catalyst.

References

American Bankers Association (ABA). *Agricultural Banker*, p. 3. Washington, D.C., Spec. Rep., Nov. 1977.

Brake, J. R., and Emanuel Melichar. "Agricultural Finance and Capital Markets." *A Survey of Agricultural Economics Literature*, vol. 1, L. R. Martin, ed. Minneapolis: University of Minnesota Press, 1977.

Martin, J. E. "Agricultural Economics: A Critical Review of the State of the Science." *S. J. Agr. Econ.* 4(1978):39–42.

Schuh, G. Edward. "The New Macroeconomics of Agriculture." *Amer. J. Agr. Econ.* 58(1976):802–11.

Competition and Regulation in the Food Industry
(Leo Polopolus, University of Florida, Chairman)

Some Basic Problems of Research into Competition in Agricultural Markets

Allen B. Paul

Equilibrium theory has come under heavy attack for its lack of realism (e.g., Kaldor; Morgenstern; and Robinson 1971, 1977). Yet, economists continue to use it on the grounds that it is the best theory available, implying that it yields testable implications (e.g., Furubotn and Pejovich).

I propose to make a modest contribution to this debate by lending support to both sides. Looking at primary agricultural markets, I will argue through most of this paper that the usefulness of partial equilibrium theory can be improved by incorporating time in a more fruitful way. But later, I will argue that for some big problems of society, we must search for a theory of disequilibrium to guide inquiry. I hasten to add that there is nothing new in this stance, although I will try to shed some fresh light on the matter.

The following discussion is divided into six topics entitled price structure and time, price discovery and market tatonnement, market form and price competition, market boundaries, dynamics of the firm and the market, and concluding remarks.

Price Structure and Time

The point to be emphasized here is that exchange involving contracts for deferred delivery introduces time as an explicit dimension. Such exchange results in three price dimensions for a commodity—one for variations in form, a second for variations in place, and a third for variation in time of delivery. The latter constitutes the time-structure of price, comparable to the more familiar form and place structures of price.

This point is not well-recognized but it is important. What is confusing is that the prices observable in each of the three dimensions, including time, tend to change over time. The observed changes tend to pervade one's thinking and dominate economic analysis. But current anticipations of how prices may differ at successive forward dates result in a current structure of prices for the forward dates.

Forward contracts, or markets in future goods as some would put it, are very clever instruments. Some theorists, notably Arrow and Debreu, have reasoned that complete use of forward contracts would result in a competitive equilibrium (see Radner). They see widespread failure to use forward contracts for all forward dates and all goods as a puzzle requiring explanation (Arrow 1974, 1978). What is not examined in such literature is the significance of such contracts, wherever they exist or can exist, for efficient organization of production in the face of market uncertainty.

Drawing on some suggestions in Hicks' *Value and Capital* and in Working's seminal article on "The Theory of the Price of Storage," I have made a start in this direction. I investigated in three cases the proposition that the purchase of a commodity for forward delivery is equivalent to the purchase of (*a*) a commodity for spot delivery and (*b*) a set of services to make the spot commodity into the forward commodity. The outcome was the identification of explicit, though indirect, markets in specialized services used to transfer a commodity in form, place, and time.

Thus, for example, the market price for a spot bushel of soybeans plus the interest cost on the soybean investment over the processing interval, when subtracted from the concur-

---

Allen B. Paul is a program leader for marketing institutions and pricing, with the National Economic Analysis Division, ESCS, U.S. Department of Agriculture.

rent price for the bushel-equivalent of soybean oil and soybean meal deliverable at the end of the processing interval, is the market price for soybean milling services per bushel (Paul 1966, Paul and Wesson 1966). Similarly, the price for a spot feeder-steer plus a spot bundle of feed sufficient to turn the feeder into a fed steer at the end of the feeding period, plus interest on the investment in feed and feeder over the period, when subtracted from the concurrent price for a fed steer deliverable at the end of the feeding period, is a market price for the feedlot sevices per animal (Paul and Wesson 1967). Similarly, the price for a bushel of spot grain plus the interest cost on the grain investment over the storage period, when subtracted from the concurrent price for a bushel of grain deliverable at the end of the storage period, is (when adjusted for convenience yield) a market price for warehousing services per bushel (Paul 1970). If one were to search, I suspect many other markets in specialized services could be identified.

Such price differences appear to respond to their own supply and demand forces in a classically predictable way. For example, a large crop represents an increased demand for storage, processing, and transport services and tends to raise their prices (i.e., widen margins). The amount of the increase depends on the elasticity of supply of services which, in turn, depends on alternative uses for a fixed stock of more or less specialized equipment. It is a rival explanation to the old complaint that when crops are large, farm prices decline excessively because buyers do not have to compete as strongly for supplies as before.

The further significance of explicit, though indirect, markets for services will be suggested soon.

Price Discovery and Market Tatonnement

The translation of traders' price ideas into market prices need not imply that successive prices will converge toward an equilibrium. There could be continuous oscillations of price. But it is useful to start with the assumption of a tendency toward equilibrium (Machlup, pp. 43–72). It could lead us, for example, to inquire how market-clearing prices are formed; whether different mechanisms for establishing price are efficient in the light of the potentials of modern electronic technology; whether the rules of trading might hinder reaching equilibrium; and whether the particular path of prices established under one set of procedures would result in a different equilibrium than under another set of procedures.

Perishable products once produced are good subjects for initial observation. They preclude significant speculation for the rise or fall of price. As commodities become storable, or as forward trading develops, speculation becomes possible and this can interfere with the tendency for the market to reach equilibrium. The main problem is that people in the market—growers, processors, merchants, and others—may not arrive at their price anticipations with sufficient rationality and independence. This is an especially rich field for investigation, and it is attracting wide attention.[1]

To show that trading behavior normally would lead to an equilibrium price, Walras visualized a process of tatonnement—the 'trial' prices and quantities that are entered and revised by buyers and sellers until a price is reached that would match the amount offered with the amount taken (Patinkin, pp. 531–40).

While it is hard to find real world examples of this "feeling-out" process that would result in a single market-clearing price during a market session, there appear to be elements of the tatonnement process in most competitive markets, e.g., the "shopping-around" that occurs in early morning hours at big public livestock markets or at big public wholesale fresh vegetable markets before substantial sales are concluded. Also, the persistence of the daily or weekly "call" throughout the history of commodity markets might be interpreted as a form of tatonnement. The "call" which usually lasts but fifteen to thirty minutes once or twice a day or week, and on whose final price many unpriced contracts are settled, has been severely criticized for being unrepresented because it usually has few actual transactions. But if its main role is to make price ideas for the day consistent with quantities demanded and supplied, by bringing all interested parties together where they can talk and bid, then the appropriate criterion for its evaluation is how well it fills this role in comparison with other

[1] One line of research is to identify and measure price oscillations in the light of conceptual and statistical difficulties. A second is to examine the causes, especially the role of market information processes, including prices as information bearers. A third is to assess the consequences of such market instability in terms of individual and social costs. A fourth is to examine the merits of the available remedies.

methods. One of the anomalies of our times is the use of the "call" in some fairly concentrated markets.

While elements of the tatonnement process may be observed in many agricultural markets, actual trades often occur throughout the market session. Thus, the final price is conditioned by the nature and sequence of preceding prices (Patinkin, p. 532). Then, does the final price better represent the equilibrium price for the quantity that changed hands during the session, than (say) the weighted average price for the entire market session?

Marshall said yes and gave an ingenious explanation (Hicks 1939, pp. 127–29). Transactions during the session that were entered at "false" prices could be viewed as having taken place at the true equilibrium price with a payment made from buyer to seller, or vice versa, equal to the difference between the true and false prices, as appropriate. If this income transfer were quite small relative to each trader's total income, it could be ignored. The final price for the session would be the equilibrium price.

Net income transfers from mistaken prices might indeed be relatively small for most market participants when a succession of market days are taken into account and the overages and underages are balanced out. Yet, one is not comfortable with the argument as it stands, especially for perishable items. It begs the question of how particular machinery pairs individual traders through the session.

Something more can be said about tatonnement if trading were for forward delivery as well as for spot delivery. Morgenstern, in "Thirteen Critical Points in Economic Theory," has prompted my thinking. The following statement is logically correct, but it can mislead one. "Tatonnement is patently impossible if among the items traded there are services or instantly perishable goods. Their supply is irreversible: once made they are gone. Services can, therefore, not even be part of tatonnement unless this is taken to be a purely hypothetical procedure and not a description of a possible physical sequence of events" (p. 1170).

While services, when produced, are instantly perishable, this does not preclude a bidding process that moves prices toward equilibrium before the services are produced. There could be a continuous process of bidding for services whose delivery would start in (say) two months time and run for a month, like the transport or warehousing of grain. As time passes, suppliers and demanders will have reevaluated their own positions in the light of the last price and, if the machinery permitted, they could liquidate existing positions or establish new ones. Note that conditions need not have changed, warranting a new equilibrium price. Rather, an iterative process would reflect the groping for the final price.

If the machinery worked well, the price established for delivery of services starting in two months could converge toward equilibrium in a short time and the price would not change much, thenceforward, unless new conditions arose to start the bidding or contracting all over again.

It is not hard to see why changes in the expected market price for services to be provided during one period may be positively correlated with changes in the expected market price for an adjacent period. Any changes in capacity of specialized equipment, or in the alternative uses for it, occur slowly. Therefore, short-run increases or decreases in demand for such services, would be spread between adjacent periods, as prices for the services of one period got out of line with prices of another (allowing for the differences in utility of the commodity in the two periods). Thus, when a service is about to be produced, it has been subjected to pricing forces over a lengthy period, and presumably the price for its current production would be near its equilibrium value.[2]

Market Form and Price Competition

Perhaps no great theorist has had a greater change of mind about the assumption of competitive equilibrium than Hicks. His *Value and Capital* was built on that assumption. Now, nearly four decades later, he has abandoned it as being too unrealistic. Hicks (1977) ob-

---

[2] A logical difficulty remains. Indirect pricing of services implies that current dispositions of commodities might be affected by changes in price for the futures commodity via changes in the spot-forward price spread. This is Morgenstern's point in another guise. No time exists for haggling over price, once services have been produced; i.e., services, being immediately perishable when produced, are immediately used up in further production. But, in practice, production in response to momentary price changes seldom occur. The difference between the specific needs of the firm and standardized agreements (which agreements must be standardized if they are to be widely used because they must provide leeway in what, where, and when delivery is to be made) causes their prices to be somewhat independent.

served, in his latest book that, in the twentieth century, flexprice markets have been

> . . . largely replaced by what I have called *fixprice* markets, in which prices are set by producers themselves (or by some authority); so they are *not* determined by supply and demand. It is of course granted that cost conditions, and sometimes also demand conditions, affect the prices that are fixed; but when these change, prices do not change automatically. . . . Organized markets, which are more competitive markets, so that they do work on the whole, in a recognizably supply-demand manner, remain in existence in some particular fields; but the unorganized flexprice market, the old type, is on the way out.
>
> That modern markets are predominantly of the fixprice type hardly needs to be verified. It is verified by the most common observation" (pp. *x–xi*).

Hicks then goes on to suggest that the principal model in Keynes *General Theory* could have been better "represented as consisting of fixprice markets (for labour and for commodities) together with just one flexprice market, the market for bonds . . ." (p. *xiii*).

Understandably, model builders must simplify, but to an agricultural economist this is too strong a dose to swallow. Assuredly, many if not most primary commodity markets are better described as flexprice markets than fixprice markets, although this in itself does not mean that they perform well. The principal exceptions (and important and perhaps growing exceptions) are those in which public authority is used to control or allocate supplies.

One clear evidence of flexprice markets in agricultural commodities is the large number traded on organized commodity exchanges. Another evidence is the large number of people that the government employs to report on a daily basis cash prices for most farm commodities. Fixprice markets for commodities tend to occur in their manufactured forms. Yet, one must be careful not to take 'list prices' as entirely trustworthy transaction prices.

Let us now turn to another observation on the nature of competition as recently given by Joan Robinson (1977, pp. 1324–25).

> The conception is absurd that a firm when it is making more than normal profits sits around waiting for competition to invade its market and drive it back towards its optimum size. It would be the height of imprudence for a business to distribute the whole of its net profit to the family or to shareholders, and no business could borrow if prospective profits did not exceed its interest bill. . . .
>
> Successful firms accumulate, finance and devour unsuccessful ones. Most joint-stock companies continue to grow, and many competitive industries tend toward a condition of dominance by one or a few firms. But the great corporations do not behave monopolistically in the sense of restricting output in order to raise prices. They continue to compete with each other, invading new markets, introducing new products, and evolving new techniques, while at the same time throwing up opportunities for new small businesses to make a start.

Do Hicks' and Robinsons' views conflict? Not necessarily. The large corporation may fix its price-line for a time, with a view of invading someone else's territory. The latter would be forced to match prices or lose customers. Thus, one cannot tell from the similarity of going prices whether there was competition or collusion. In either case, to use Hicks' term, we would observe a "fixprice" market. Other sorts of evidence would be needed to make up one's mind.

This is why, I believe, that Bressler and his associates did not trust any inferences about the price performance of agricultural industries from the numbers of firms in the market. They preferred the laborious process of comparing observed prices for a commodity (in form, place, and time) with costs of physical transformation that would be incurred by any firm that would operate with a modern equipment of efficient scale. In this manner they hoped to identify excessive costs as well as excessive profits. I do not think Bressler was concerned with how frequently prices flexed within the day or week. It was the average level price that concerned him.

The average level of price also concerns industrial organization economists. Their extensive empirical studies usually show positive correlations between concentrated industries and price levels or profit rates. In contrast to the Bressler School, they deal at a fairly aggregative level of observation, which procedure causes problems of interpretation. But both rely on partial equilibrium theory to determine the social cost of market imperfections. It may be the best theory we have, but it cannot tell us much about the relation between economic growth and industrial organization and, therefore, not much about the nature of market deficiencies when markets are in chronic disequilibrium.

A final point. There are some services, produced by a small number of firms, whose prices do fluctuate from day to day almost as if they were determined in an atomistically competitive market. For example, U.S. soybean-

processing services are produced by about 20 firms, yet the price for soybean-crushing services fluctuates as if there were 200 firms. Either our definition of the industry is too narrow, or oligopolies may behave like atomistic competitors. How should one define an industry? We usually say that it is all firms that make a single product or a group of related products, but then we must define these terms.

Market Boundaries

A single product has some unique form, place, and time specification in the eyes of buyers. They regard it as having a separate market. Marshall set forth in lucid style the principles by which we can set boundaries to a market in each of three dimensions, but his time dimension is of a different sort than the one I have emphasized. Quoting Cournot, Marshall said that a market is "not any particular market place in which things are bought and sold, but the whole of any region in which buyers and sellers are in in such free intercourse with one another that the prices of the same goods tend to equality easily and quickly" (p. 324). The "same goods" are things that can be described easily and exactly so that they "can be brought and sold by persons at a distance from one another and at a distance also from the commodities" (p. 326). With respect to time, Marshall said that the "element of Time requires more careful attention just now than does that of Space. For the nature of the equilibrium itself, and that of the causes by which it is determined, depend on the length of the period over which the market is taken to extend. We shall find that if the period is short, the supply is limited to the stores which happen to be at hand; if the period is longer, the supply will be influenced, more or less, by the cost of producing the commodity in question; and if the period is very long, this cost will in its turn be influenced, more or less, by the cost of producing the labour and the material things required for producing the commodity. These three classes, of course, will merge into one another by imperceptable degrees" (p. 330).

The importance of distinguishing between short-run and long-run market behavior is now well-known. Arguments can be avoided over whether an industry is essentially competitive or monopolistic, by making explicit one's assumptions about length-of-run. Or, arguments might be moved onto grounds that allow for resolution, e.g., is the difference over how long the long run must be? Or, if not, is there a difference over possibilities of entry by outside firms?

If one can get agreement on the boundaries for the short-run market (which may not be too difficult for most agricultural output), the setting of place and form boundaries require care. I recall congressional testimony some years ago describing how one meat-packer that had averaged about 40% of the daily cattle purchases at the Denver stockyards, had manipulated price by suddenly withdrawing in favor of cattle from its own feedyards when Denver cattle prices had risen, thereby precipitating a drop in price. But the actual price experience showed that after the firm had withdrawn from the Denver market, prices continued to climb for some weeks before turning down; when the firm had reentered the market after prices had weakened, prices continued to decline. These facts suggest that for purposes of measuring market shares the market was too narrowly bounded. While fed cattle ordinarily do not move great distances, chilled beef carcasses do. Thus, prices for fed cattle in many local markets probably were closely tied by a regional or national meat market. Evidently, the Denver packer was a much smaller factor in the relevant market than 40%.

Having said this, one should point out that geographic isolation of markets for agricultural commodities is a common and perhaps growing condition in the United States. It is aggravated by increased economies of scale in processing, transport, storage, buying, and other operations under advancing technology that result in fewer, larger units. These monopoloid conditions deserve careful study.

The idea that two stages of a commodity are closely interrelated through production, of course, has its counterpart in consumption. Unless one has reliable cross-commodity demand elasticities for the relevant time period, he may have no good basis for counting firms.

Now we will go beyond Marshall's concept of time. What can one say about competition and market boundaries when a market for future goods exists? The key idea is that a time structure of commodity prices implies the marketing of services. The dilemma of the existence of a flexprice market for a fairly concentrated U.S. soybean-crushing industry may be explored in this light. But first we should correct the number of decision makers.

Some firms may have delegated buying and selling decisions to individual plant managers where the profitability of the plant is sensitive to local conditions. (The twenty companies of the 1972 census operated sixty mills.) Also, foreign demand for U.S. soybeans implies a demand for services of mills in Europe, Japan, and elsewhere. And some U.S. cottonseed, flaxseed, and other vegetable oil mills can crush soybeans to advantage when their own season is done.

But we must look beyond numbers of decision makers and see what they see. A U.S. plant manager usually looks at the rate at which beans might become available in his territory, their likely condition, his expected costs of carrying beans to later months, and the expected change in the rate of oil extraction. Conditions affecting these prospects tend to change during the season; hence, it is in the interest of each firm to redo its contracts in the light of new information.

An important point now emerges. Within the interval between entering into and fulfilling a contract, the processing, transport, and storage services are, within limits, excellent substitutes. For example, a contract to deliver soybean oil and meal in Chicago in three months could be filled in various ways—e.g., if the beans could be processed either in Iowa or Chicago, and if beans or the bean products could be stored at either location, then there would be at least six combinations of (the locus of) the processing, transport, and storage services that could be used to satisfy the same contract. Each combination is a near-perfect substitute for another. Thus, the market boundaries for commodities in which there is active trade for forward delivery may be very broad.[3]

Dynamics of the firm and the Market

Partial equilibrium theory cannot explain the recurrent upsets of equilibrium states nor the changing structure of markets. If as Joan Robinson says successful firms "accumulate, finance and devour unsuccessful ones (and) . . . continue to compete with each other, invading new markets, introducing new products, and new techniques, while at the same time throwing up opportunities for new small businesses to make a start" (p. 1325), what sort of theory would this suggest? I think that technological change and economic growth would have to be at the center of such a theory, but so would institutional change.

To explain the changes in agricultural markets, I became attracted to Allyn Young's thesis that market growth begets specialization and, in turn, specialization begets market growth. But it lacks an important feature. It does not explain how the capital needed for new kinds of production can be mobilized in the face of economic hazards. This usually requires institutional adaptation. Allyn Young probably did not address this issue because it was not important for his purposes.

The evolution of successful techniques to mobilize savings and channel it into investment in the modern age could not have happened without two basic discoveries: namely, that (*a*) debt could be sold to third parties by reducing prospects of default, and (*b*) residual claims to income from business ventures could be made salable by limiting the claimant's liability for losses. It has taken several centuries to fashion the modern techniques and put them onto a secure legal footing. Moreover, practical applications are still evolving. For example, while the issuance and sale of corporate shares are generally sanctioned, the issuance and sale of commodity options are not. Both are applications of the limited liability principle to residual claims.

The two great social inventions—salability of debt claims and equity claims—were just as important as the great physical inventions—steam, internal combustion, and electric engines—in laying the foundations for modern economic growth. And like machines, institutions incorporate what has been learned. It is the almost endless elaboration of these basic social inventions into new and different arrangements to suit different purposes that a dynamic theory of markets should provide for.

To bring such institutions into a theory, I have suggested elsewhere (Paul 1974) a recursive system involving two quite different sets of forces—one "real" and the other "institutional"—interacting one on the other over time. Briefly stated, specialization of

[3] A common error is to draw boundaries around a particular set of trading arrangements. For example, boundaries are drawn around organized futures markets, as if so-called cash markets had no trading for future delivery, nor futures markets any trading for immediate delivery. Neither is true. Markets also need to be bounded in terms of what the commodity is exchanged for—i.e., dollars or other currency that can be readily converted into dollars. But, if there are impediments to conversion of currencies, how far should one go in allowing all international forces within the framework of a single commodity market?

production (with attending enlargements of scale and further applications of technology) marches on in a growing economy, as both a cause and a consequence of growth, but at no faster pace than permitted by the reduction in investment hazards through public and private techniques, which techniques are themselves a cause and consequence of economic growth. Of course, for a time, someone may forge ahead with a specialized operation in a new area and assume big risks. But where many do so and fail, there will be a search for institutional accommodations to spread risks.

The private techniques are of two types. One type comprises enterprise-sharing arrangements under which capital from diverse sources is pooled and put under the command of a single agent—as manifested in syndicates, partnerships, and corporations. The other type comprises enterprise-sharing arrangements that bind sufficient capital to a specified course of production by voluntary agreements among sovereign economic units—as manifested in joint-account production, participation agreements, and deferred delivery contracts of various sorts.

The public methods of mitigating economic hazards include schemes to underwrite loans, insurance coverage, income, and employment. These schemes tend to free private capital for investment in new and untried ventures, which ventures in the aggregate further increase output, which increased output then favors more public schemes. And so this circular process continues.

The main thing to be said about private arrangements is that the two major types are interdependent. That is, the organization of more economic activity under the command of a firm is, within limits, an alternative to the organization of such activity among firms through the market. Therefore, failures of markets to perform well make for more activity within the firm, whereas failures of the firm to perform well make for greater reliance on markets (Williamson). The market should provide, as effectively and economically as possible, information, performance guarantees on contractual agreements, and settlement of disputes. The firm should play each of its roles effectively and economically—e.g., deciding on production techniques; hiring, training, and rewarding personnel; gathering and using pertinent information; positioning assets to best advantage; complying with government regulations; and so on.

Some firms are bigger than required to achieve optimum performance in any of these roles, (although evidence that this is so or not so can be misleading). Command over large-scale equipment or large efforts to develop advanced equipment requires large firms. But what explains firms that are even larger?

Caves recently provided an explanation for the grain-exporting industry and advanced three reasons why firms must be large—i.e., they must minimize unused grain storage capacity in dispersed locations, they must reduce variance in returns from "basis" fluctuations, and they must be efficient at gathering timely information about grain markets throughout the world. While his inquiry is on the right track, by examining highly disaggregated enterprises, one still needs to ask: How large must a firm be in each area to compete successfully?

To satisfy such a query about any industry, one should examine whether the bigness of the firm compensates for deficiencies in market mechanisms for loans, enterprise shares, insurance, and foreign currency, as well as for goods and services. If so, the question becomes whether deficiencies in any of these markets can be remedied, how, at what cost, and whether the large firm is itself a help or hindrance to improvement. Among other things, one also should study the culture and pathology of financial institutions including tax laws. This is a tall bill to present to economists, but it is a worthy one.

Concluding Remarks

My intent in this paper was to give a somewhat personal view of how to deepen our insights into basic market processes for the primary commodities. The two different paths that have been followed reflect a deep split among some of the best minds of the economic profession on how to proceed. I am not sure that the differences can or will be resolved because, as Joan Robinson has observed, there is a strong ideological underpinning to choice of method. But this is an old and staying problem of the profession. Perhaps more scientifically-based empiricism would help us through.

References

Arrow, K. J. "Limited Knowledge and Economic Analysis." *Amer. Econ. Rev.* 64(1974):1–10.

———. "The Future and the Present in Economic Life." *Econ. Inquiry* 16(1978):157–69.

Bressler, R. "Market Structure and Performance—The Conceptual Framework." *Proceedings of Market Structure Workshop*. North Central Regional Extension Marketing Committee, Purdue University, 1966.

Caves, R. E. "Organization, Scale, and Performance in the Grain Trading Industry." Harvard University Institute of Economics Disc. Pap. No. 546, 1977.

Furubotn, E., and S. Pejovich. "Property Rights and Economic Theory: A Survey of Recent Literature." *J. Econ. Lit.* 10(1972):1137–62.

Hicks, J. R. *Value and Capital*. Oxford: Clarendon Press, 1939.

———. *Economic Perspectives*. Oxford: Clarendon Press, 1977.

Kaldor, N. "What is Wrong with Economic Theory." *Quart. J. Econ.* 89(1975):347–57.

Machlup, F. *Essays on Economic Semantics*. Englewood Cliffs, N.J.: Prentice-Hall, 1963.

Marshall, A. *Principles of Economics*, 8th ed. London: Macmillan and Co., 1938.

Morgenstern, O. "Thirteen Critical Points in Economic Theory." *J. Econ. Lit.* 10(1972):1163–89.

Patinkin, D. *Money, Interest, and Prices*, 2nd ed. New York: Harper & Row, publishers, 1965.

Paul, A. B. "Pricing Below Cost in the Soybean-Processing Industry." *J. Farm Econ.* 48(1966):1–22.

———. "The Pricing of Binspace: A Contribution to the Theory of Storage." *Amer. J. Agr. Econ.* 52(1970):1–12.

———. "Role of Competitive Market Institutions." *Agr. Econ. Res.* 26(1974):41–48.

Paul, A. B., and W. T. Wesson. "Short-Run Supply of Services—The Case of Soybean Processing." *J. Farm Econ.* 48(1966):935–51.

———. "Pricing Feedlot Services through Cattle Futures." *Agr. Econ. Res.* 19(1967):33–45.

Radner, R. "Rational Expectations Equilibrium With Differential Information." Tech. Rep. OW-12, Center for Research in Management Sciences, University of California, Berkeley, 1978.

Robinson, J. *Economic Heresies*. New York: Basic Books, 1971.

———. "What are the Questions?" *J. Econ. Lit.* 15(1977):1318–39.

Williamson, O. E. "The Vertical Integration of Production: Market Failure Considerations." *Amer. Econ. Rev.* 61(1971):112–23.

Working, H. "The Theory of the Price of Storage." *Amer. Econ. Rev.* 39(1949):1254–62.

Young, A. A. "Increasing Returns and Economic Progress." *Econ. J.* 38(1928):527–42.

Government Regulation of Competition in the Food Industry

Bruce W. Marion

Given my assigned task, I could journey in many directions. But in the interest of brevity and to avoid traveling beyond the bounds of my expertise, I will concentrate on those government policies designed to deal specifically with competition in the U.S. economy—the antitrust laws.

In doing so, I will necessarily bypass some important regulations that directly or indirectly affect competition in the food industry. Marketing orders, the Perishable Agricultural Commodities Act, Capper-Volstead, the Food and Drug Administration (FDA), and the Commodities Futures Trading Commission are some areas that immediately come to mind, although other governmental policies such as taxation, subsidies, and public purchases may also have considerable impact. Similarly ignored are the effects of the antitrust laws—or the exemptions therefrom—on the organization and performance of those sectors such as finance, transportation, labor, and utilities which provide important inputs or services to the food system. Clearly, this panoply of forces can have important effects on the competitive organization and performance of the food industry and should be considered in an all-encompassing analysis.

In examining the antitrust laws and their effects, I will concentrate on three areas: (*a*) Given the content and interpretation of U.S. antitrust laws, what effects are suggested by the pattern of enforcement? (*b*) What are the competitive characteristics and trends in the food industry? What insights do these provide on the impact of antitrust laws? (*c*) What insights into the impacts of U.S. antitrust laws are provided by the experiences in other countries?

Considerable debate has occurred concerning the economic foundations on which antitrust policy is or should be based. These debates frequently find members of the so-called "University of Chicago school" on one side and a variety of industrial organization economists on the other. Since I (Marion and Sporleder), as well as many others (Goldschmid, Mann, Weston, Shepherd and Williamson, to name but a few) have attempted to evaluate the economic bases for antitrust, I will largely bypass this very critical issue, as well as any discussion of the content, objectives, and interpretations of the antitrust statutes.

My approach will be pragmatic. Given my assessment of the theoretical and empirical evidence concerning the interrelationships between industry structure, conduct, and performance, what impacts on competition are indicated by the interpretation and enforcement of the antitrust laws and by the evolving competitive characteristics of the food industry? In taking this approach, I recognize I am vulnerable to the criticism that I have bypassed the most critical and controversial issues—as indeed I probably have.

Enforcement Patterns

An analysis of past enforcement provides useful insights into the types of violations pursued and the industries most frequently involved. However, it may provide a distorted indication of the total impact of the laws and the enforcement agencies. Industry guidelines and advisory opinions are provided by both the Federal Trade Commission (FTC) and Justice Department concerning the legality of various actions; the FTC also has the authority to issue trade regulation rules. These actions do not show up in a summary of litigation initiated, yet may have substantial effects on competitive practices.

The number of cases brought also indicates little about their relative importance. With relatively limited resources, both agencies must

---

Bruce W. Marion is an agricultural economist with ESCS, U.S. Department of Agriculture, and adjunct professor, University of Wisconsin-Madison.

The views expressed here do not necessarily reflect the position of the U.S. Department of Agriculture.

choose between a few "big cases" and many smaller ones. Given these and other limitations of enforcement data, they are a useful starting point.

Data are available for antitrust cases in the food industry during two time periods, 1950–65 and 1966–77 (NCFM 1966a, b; Grant, Dahl, Geyer; Mueller 1978). The activity of the Justice Department in the two periods was similar—slightly less than five cases per year. The number of complaints brought by the FTC dropped sharply from about 13.0 per year during 1950–65 to 3.7 in the most recent period.[1]

The nature of the violations alleged and the industries involved provide some insights into likely enforcement effects. To the extent possible, cases were categorized by Parker's classification of food manufacturing industries (producer goods and low, medium, and highly differentiated consumer goods).[2] Cases were categorized by the following types of violations: (*a*) price fixing and allocation of markets; (*b*) tying arrangements, boycotts, refusal to deal, reciprocity, and patent abuse; (*c*) monopolization or attempts to monopolize; (*d*) predatory pricing (primary line price discrimination); (*e*) secondary line price and service discrimination; (*f*) mergers.

In both periods, 80% of the Justice Department cases alleged price fixing or allocation of markets. Tying arrangements, boycotts, etc., were alleged in 10% of the 135 cases over the twenty-eight-year period but nearly half also included price-fixing charges. Approximately one-half of these two types of cases involved either dairy (mostly fluid milk processors) or bakery firms which share the common characteristics of operating in local or regional markets in which there is relatively high concentration on both the buying and selling sides of the market. Both bread and milk are extremely important competitive products for retailers and are the products most frequently processed by retailers. The National Commission on Food Marketing commented, "the relative power of chainstore buyers is greater in dairy than perhaps any other area of food manufacturing with a possible exception of baking," (NCFM 1966b, p. 165). (Table 1.)

Nearly two-thirds of the above cases involved either producer goods or low differentiated consumer goods, 22% moderately differentiated consumer goods, and only 4% involved manufacturers of highly differentiated products. Even allowing for some errors in classifying cases, enforcement has been heavily concentrated in local market industries with relatively homogeneous products.

Other food cases brought by the Justice Department were the following:

	1950–65	1966–77
Monopolizing	11	4
Predatory pricing	7	0
Mergers	7	11

Over half of the monopolizing and predatory pricing cases involved dairy firms. Five of the fifteen monopolization cases involved dairy cooperatives. Manufacturers of highly differentiated products are noticeable by their low representation in all Justice Department cases except those challenging mergers. Seven of the seventeen merger cases involved such firms.

The data available on FTC complaints are more difficult to classify. Of the 211 complaints in the food industry during 1950–65, two-thirds alleged Clayton Section 2 violations

Table 1. Distribution of Justice Department Price Fixing and Tying Arrangements Cases by Type of Industry, 1950–77

	1950–1965		1966–1977	
Producer goods		3		8
Consumer goods—low differentiation		45		17
Milk and dairy products	22		11	
Meat and broilers	9		2	
Fish and seafood products	7		1	
Fresh fruits, vegetables, and nuts	5		2	
Other	2		1	
Consumer goods—medium differentiation		11		15
Bakery products	8		15	
Other	3		0	
Consumer goods—high differentiation		1		4
Snack foods	0		4	
Other	1		0	
Grocery retailers		5		4
Other wholesale and retail distributors		0		4
Total		65		52

[1] The eighty-two illegal brokerage cases brought as a group against citrus firms and twenty-eight illegal brokerage cases brought as a group against salmon firms during 1950–65 are counted as two cases.

[2] One important adjustment in Parker's classification was made: fluid milk was switched from the medium to low differentiated consumer-goods category because recent data on advertising and private label-national brand price differences suggest that is the more appropriate category.

(see footnote 1), one-fourth alleged violation of Section 5 of the FTC Act and the remainder challenged mergers. Slightly over half of the complaints during this period involved dairy, fruit and vegetable, fish, or bakery firms.

Only forty-five complaints were brought during 1966–77. The violations alleged were as follows:

Price fixing (2) and market allocation (8)	10
Tying arrangements, boycotts, etc.	4
Monopolizing	5
Predatory pricing	3
Price and service discrimination	13
Mergers	12
Total (involves double counting)	47

Manufacturers of highly differentiated products were involved in about one-third of the FTC complaints during 1966–77. Several major cases were brought during the period including eight soft drink territorial restriction cases, the ReaLemon monopolization case, and the cereal shared monopoly case. Retailers were involved in one-fifth of the cases.

A more comprehensive analysis of merger law enforcement is provided by Mueller (1978). During the twenty-six years since the Cellar-Kefauver Amendment of Section 7 of the Clayton Act, the FTC and the Justice Department have challenged 9% of all large mergers (assets over $10 million). Challenged mergers represented 20% of assets acquired through large mergers. Nearly two-thirds of the challenged mergers were horizontal mergers. Only 20% of the mergers challenged were conglomerate (mostly product extension) although over 70% of all large mergers during the twenty-six-year period were conglomerate mergers. Mueller concludes that Section 7—as enforced—has been relatively effective in dealing with noncompetitive horizontal acquisitions but ineffective in dealing with conglomerate acquisitions, which have steadily increased since 1950.

Within the food industry, a strong stance by antitrust agencies against horizontal and market extension mergers by leading dairy-processing and food-retailing firms virtually stopped these types of acquisitions for about a decade (Mueller, Hamm, Cook; Marion et al.). The total number of mergers in these industries did not decline, but were channeled to small- and medium-sized firms. Since the mid-70s, the antitrust agencies have relaxed their posture on food industry mergers. A recent surge in mergers by large grocery chains appears to be a direct response.

Action against product extension conglomerate mergers has had less impact. Although the FTC's "Enforcement Policy With Respect to Product Extension Mergers in Grocery Products Manufacturing" was in effect from 1968 to 1976, relatively little effect on the merger activity of large food manufacturers during this period is apparent (Mueller 1978).

Given the foregoing summary of antitrust enforcement patterns, what can we conclude? Except for some rather solid data on merger enforcement, relatively little can be said with confidence. There is rather convincing evidence that the Cellar-Kefauver Amendment has affected and can still significantly affect the structure of markets if it is vigorously enforced. Its effects on aggregate concentration and on the growth of conglomerates is more open to question, however. The data indicate a strong emphasis by the Justice Department on Section 1 (Sherman) violations, often price fixing, in industries handling relatively undifferentiated products. Given the emphasis on horizontal conspiracies, the predominance of firms producing relatively homogeneous products is not surprising. Firms selling highly differentiated products have considerable control over price and need not seek collusive agreements to regulate supply or price.

Many students of antitrust have noted the paucity of cases that challenge established positions of monopoly power. There is a strong question whether existing legislation enables the antitrust agencies to challenge entrenched monopoly power. Section 2 of the Sherman Act is characterized by Shepherd (p. 184) as "nearly a dead letter" and is infrequently applied. Section 5 of the FTC Act was used to challenge successfully Borden's monopolization of the reconstituted lemon juice industry. Its applicability to concentrated oligopolies is being tested in the "shared monopoly" cereal case.

Antitrust enforcement to date has also had limited effects on advertising, the primary means of differentiating products, and on conglomerate mergers. As evidence grows that these two factors are the most powerful weapons to restructure industries, this weakness in antitrust policies may prove the most fatal of all (see for example, Mueller and Rogers, Mueller 1975 and Scherer).

Competitive Characteristics and Trends in Food Industries

Although the characteristics of the laws and the level of enforcement provide some insights into the likely areas where antitrust regulations have had effect, in the end, it is the results that count. Thus, we must ask if there is evidence that antitrust policy has led to more desirable economic performance and a more equitable distribution of power in the food system than would have occurred without antitrust. Because this is a counter-factual proposition that cannot be tested, a second alternative is to assess the competitive characteristics and trends in the food industries—keeping in mind the emphasis of past antitrust policies.

Although the antitrust laws clearly concentrate on conduct, it is safe to assume that if the laws have been effective in influencing conduct, industry structure and performance have also been affected. Since data are not available on conduct, the competitive characteristics of the food industries must be judged by structure and performance indicators. Only food manufacturing and food retailing are considered because antitrust agencies have shown little interest until recently in producer-first handler markets. Inadequate data also makes these markets difficult to evaluate.

Structure and Performance of Food Manufacturing Industries

The National Commission on Food Marketing identified six major changes that carried important implications for competition in food manufacturing industries. They noted: (*a*) a decline in company numbers, (*b*) an increase in concentration, (*c*) a substantial increase in the conglomerate nature of leading food manufacturing firms, (*d*) an increase in the number of large acquisitions by the larger companies, (*e*) substantial increases in product differentiation expenditures by large food manufacturers, and (*f*) a growing differential between the profitability of large versus medium and small food manufacturers.

Connor examines each of these changes using 1972 and 1975 data and concludes that in every instance except the last one—where data are not available on the profitability of small companies—the trends have continued. Some of the highlights of Connor's finding are as follows.

The number of food manufacturing companies has shown an accelerating rate of decline since World War II, while the number of companies in the rest of manufacturing has been gradually increasing. By 1972, there were 23,326 food manufacturing companies, approximately one-half the number in 1947.

Average four-firm concentration in food manufacturing industries has gradually increased to 54.7 in 1972.[3] This is considerably higher than concentration in the rest of manufacturing (43.3). Approximately 70% of the value added in food manufacturing in 1972 came from industries that were moderately to very highly concentrated oligopolies by Bain's classification (CR_4 over 50, or CR_8 over 70).

The largest 100 food manufacturers in 1975 made slightly over half of all U.S. food and tobacco shipments. The largest 200 firms represented nearly two-thirds of all shipments. Aggregate concentration has increased.

Evidence suggests that the largest food manufacturing companies have diversified into other food manufacturing industries, into industries outside food manufacturing and internationally. In 1972, the largest 162 companies classified as primarily food manufacturers realized only 60% of their sales from U.S. food and tobacco sales.

Food- and tobacco-manufacturing companies have increasingly been involved in acquisitions, either as the acquired or acquiring firm. Between 1971 and 1975, food- and tobacco-manufacturing firms made over one-fourth of all large manufacturing acquisitions.

Media advertising by food and tobacco manufacturers totalled over $3 billion in 1977, nearly double the amount in 1967. The 200 largest companies accounted for 84% of the total. These companies do a disproportionate share of their advertising by television (80% versus 37% for the remaining companies). The largest 50 companies alone did 70% of all television advertising of food and tobacco products.

The profitability of food manufacturing companies, which was lower than the rest of

[3] When national concentration ratios are used for all food manufacturing industries, the weighted average four-firm concentration is similar to the rest of manufacturing. For 107 product classes that are comparable for 1963, 1967, and 1972, the weighted average four-firm concentration ratios were 37.5, 38.5, and 42.3, respectively. Because local market industries are more important in food manufacturing than in the rest of manufacturing, use of the more relevant local market concentration ratios for fluid milk, ice cream, bread and related products, prepared feeds, and bottled and canned soft drinks results in a much greater increase in average concentration for food and tobacco manufacturing.

manufacturing during 1951–65, was 13.2% of stockholder's equity during 1971–75, or 11% higher than the rest of manufacturing.

The significance of increased concentration, acquisitions, conglomeration, and advertising is not fully understood. There is growing evidence that they are interrelated trends; that is, that acquisitions are a major vehicle for conglomeration, and that entry by large conglomerates into some industries has been associated with intensified advertising and rivalry—often of a cost-increasing type—and tends to further concentrate sales in the hands of leading firms.

As economists, we are endowed with a strong dose of economic determinism. If firms are becoming more conglomerate and industries more concentrated, we search for failures in capital markets or economies of scale as logical explanations. After all businessmen are rational, are they not? Although once again the evidence is rather limited, it suggests that these are not the predominant reasons for the existing trends (Scherer, p. 985–95) Mueller and Rogers, in a recent study of structural changes in all U.S. manufacturing industries, found a strong positive relationship between the level of television advertising and increases in concentration. They found that in producer goods industries, concentration is stable or declining while it has increased in consumer good industries, especially those with high product differentiation.

Food-manufacturing industries are predominantly consumer goods industries. The available evidence suggests that concentration trends in food manufacturing are similar to those in all manufacturing; i.e., that changes in concentration are strongly associated with the level of product differentiation.

Finally, the fragility of market power carries important implications for antitrust policies, for if forces are continually at work to erode market power and to ensure that it is short-lived in duration, the current trends in food manufacturing are of less concern. Although there are many examples of market power situations that have dissipated over time, present day market power—which is more heavily based upon product differentiation and conglomerate-derived economic power than in previous periods—appears much less vulnerable to erosion.

The characteristics of food manufacturing that raise the most serious questions about the effectiveness of future competition are precisely in those areas where antitrust has been relatively mute—concentrated oligopolies, the growing dominance of conglomerates, conglomerate acquisitions, increasing aggregate concentration, and high levels and concentrations of advertising. As presently interpreted and enforced, the antitrust laws have had their greatest impact on maintaining fair and effective competition in "commodity oriented" industries which are structurally the most competitive, and where market power positions are the easiest to dismantle.

Competitive Characteristics of Food Wholesaling and Retailing

Based upon our recent study (Marion et al.), trends that have particular relevance for competition in these industries are as follows.

National concentration of food wholesaling and food retailing has experienced a gradual increase during the last twenty years. Grocery chains expanded their share of grocery store sales from 37% in 1948 to 57% in 1972. The largest twenty chains in 1972 accounted for two-thirds of the chain share. National concentration of sales among the leading grocery wholesalers is roughly comparable and has increased more rapidly. Thus, concentration of procurement has increased at the wholesale-retail level since that National Commission on Food Marketing voiced alarm on this subject in the mid-60s.

Concentration of grocery store sales in local markets has increased steadily. Although many markets are still relatively competitive in structure, the proportion of Standard Metropolitan Statistical Areas (SMSAs) in which the largest four retailers account for 60% or more of sales has increased from 5% in 1954 to 25% in 1972.

Large grocery chains operate across an increasing number of markets, providing greater opportunities from cross-subsidization and conglomerate mutual forbearance.

Horizontal and market extension mergers by the largest twenty chains virtually stopped during 1965–75 due to the strong merger stance of FTC. Acquisitions by conglomerate firms not previously in food retailing increased substantially during this period. Change in SMSA concentration was positively associated with the presence of conglomerate firms (including multimarket food chains) in local markets.

Since grocery chain prices and profits in different SMSAs were found to be positively associated with the relative dominance of a chain and the four-firm concentration level, these trends are of considerable public concern. Past antitrust activity in food wholesaling has been nil; in food retailing, enforcement has focused largely on price and service discrimination by suppliers, mergers (particularly horizontal but also including sizeable market extension mergers from 1959 to 1976), some unfair and deceptive practices, and a few bribery and market manipulation cases. These actions probably have helped police the substantial procurement power of large retailers and may have prevented a more rapid increase in local and national concentration via mergers. Antitrust agencies have had relatively little to say about metropolitan markets with dominant firms or high concentration, restrictive site arrangements, saturation advertising, and predatory geographic price discrimination used to ward off new entrants or the growth of existing firms, conglomerate mergers, or the level of consumer information on food products and prices. As in food manufacturing, antitrust has had relatively little effect on those issues that are of greatest concern for the future competitive viability of these industries.

Observations from Antitrust Activity in Other Countries

Since comparative studies of the substance and effect of antitrust laws are relatively scarce, only a few observations are possible. Outside of the United States, laws designed to curb cartels and monopolies were rare before World War II. However, in the twenty years following World War II, laws to curb restrictive practices were developed in all non-Communist Europe except Italy, Greece, and Turkey, and in Japan, New Zealand, Israel, Argentina, Colombia, Brazil, and South Africa. From his analysis of these laws, Corwin Edwards concludes that, in general, the laws in these countries are (*a*) more permissive in the treatment of horizontal agreements and combinations (e.g., price fixing, terms of sale, mergers), as long as prices and performance are considered "fair"; (*b*) similar in the treatment of collective activity designed to coerce independents, exclude enterprises from markets, or impose discriminatory disadvantages on them; and (*c*) more restrictive in treating refusals to sell, vertical price fixing, and prices charged by powerful single firms. In several countries, government has some control over the prices of powerful firms.

While many of the laws had been in effect for only a decade when Edwards did his study, he found their impact had been substantial. The number of restrictive agreements were reduced, coercive and exclusionary pressures on independent enterprises had declined, and there was some evidence that surveillance over prices had kept prices down in some countries.

Some lessons are also available from our neighbor to the north. Canadian antitrust laws, as interpreted and enforced during this century, have placed less emphasis on horizontal combinations and restraints than in the United States, and more emphasis on industry performance. This has resulted in relatively modest antitrust action in Canadian food industries. At least in part, this may explain the considerably higher levels of local market concentration of food retailing in Canada vis-a-vis the United States. Average four-firm concentration in 32 Canadian cities was 68 in 1973 (Mallen), compared to 52 for 263 U.S. metropolitan areas in 1972 (Marion et al.).

Conclusions

John Galbraith has labeled our antitrust laws a "charade." He contends: "It (antitrust activity) conducts a fairly effective war on small firms which seek the same market power that the big firms already, by their nature, possess. . . . The antitrust laws give the impression of protecting the market and competition by attacking those who exercise it most effectively. . . . Behind this impressive facade the big participants who have the most power bask in nearly total immunity" (p. 8).

Although put more forcefully than others, Galbraith's position has a great deal of support (e.g., Kaysen and Turner, Neal Task Force, Shepherd, Mueller 1975). Other evidence adds fuel to such a sobering view of antitrust.

The typical antitrust case is long—average of four years for Justice Department-litigated cases and three years for contested FTC cases (Posner)—complex, and often very expensive (AT&T is expected to spend $60 million defending itself). Antitrust agencies are underfunded to take on large cases and are handicapped further by rapid staff turnover. Mueller (1975) has characterized the situation:

"Under existing circumstances the antitrust agencies are outnumbered, outgunned, and are forced to fight on the defendent's terms. Today an antitrust confrontation (with large firms) more closely resembles Custer's last stand than a shoot-out at the OK Corral" (p. 170).

Remedies in antitrust cases are relatively impotent. Only 4% of the monopolization cases brought by the Justice Department since 1950 led to significant divestiture or dissolution. Cases where divestitures were involved were also particularly lengthy—approximately seven years. Imprisonment has been part of the penalty in less than 4% of Justice Department criminal cases, with prison terms less than a year in nearly all instances. Fines imposed in criminal cases won by the Justice Department during 1960–69 averaged $120,000 per case. Until 1969, only two cases involved fines of more than $1 million. In contrast, horizontal conspiracies challenged by the Justice Department during 1960–69 operated, on average, for an estimated six years and involved approximately $160 million in sales (Posner). Although the last figures may be only crude estimates, they indicate why white collar crime can pay handsomely—even when the culprit is caught.

Given such evidence, it is easy to become pessimistic about the future of the antitrust laws and decide in the interest of kindness to "allow them quietly to atrophy" (p. 11), as Galbraith has suggested. However, we must be careful not to judge antitrust efforts totally by their failures. Although antitrust policy to date has been incapable of dealing with some of the major competitive concerns in the food industry, it very likely has helped preserve competition in those industries with relatively low product differentiation. There are few economists or businessmen that I know who would seriously suggest abandoning antitrust.

However, it is high time to face up to the strengths and limits of antitrust. Given the characteristics and trends in the U.S. economy, we can ill afford to continue to delude ourselves that the competitive behavior of powerful firms is adequately policed when in fact it is not.

Given the response to the numerous scholars, commissions, and task forces that have studied U.S. antitrust policy and recommended changes, perhaps it is folly to think that any substantive changes will be made. In my more realistic moments, I suspect this is true. The citadels of economic power have learned well how to translate this power into power in the public sector. However, I feel obliged to close with some positive proposals for more effective antitrust policies.

Like many others, I place a heavy emphasis on the need for much more information about the activities of large business firms, and on the right of the public to this information. Federal chartering with attendant information requirements is one approach. FTC's Line-Of-Business Reporting program is another, if it survives court challenge and business efforts to sabotage the program by political means,[4] and if the data are made public without unnecessary delays.

Second, I believe the time is right to take on what Scherer (p. 998) calls "a high megatonnage time bomb"—advertising. The evidence concerning the effect of advertising on consumer preference, firm profitability, barriers to entry, and the restructuring of markets, and the fact that advertising messages are transmitted over public media provides a strong rationale for considering advertising a quasi-public good and subjecting it to greater public control. Although some of the initiatives that have been taken in the last decade to deal with advertising (e.g., affirmative disclosure, substantiation of claims) have been constructive, they do little to control the most powerful aspect of advertising—imagery.

Scherer has suggested the licensing of trademarks as a way of eroding the market power of strong brands. For products where brands have taken on generic meaning such as Clorox, Jello, or ReaLemon (this was the recommended relief in this case) this remedy seems particularly appropriate. It might also be used in connection with divestitures in cases where multiple plants and marketing areas allow breaking a company into several entities. A more drastic measure that some may find offensive is to establish ceilings on the amount large firms can spend on the advertising of various product classes. While I can anticipate some of the counter arguments, I place a higher priority on the rights of a society to choose its future social and economic characteristics than on the rights of business.

In addition, I suggest that our laws concerning discrimination and predation should be applied to nonprice forms of competition—particularly advertising—similar to the way

[4] In March 1976, FTC Commissioner Dixon identified thirty food manufacturers that were opposing the Line-Of-Business program. Only four had sales less than one billion per year.

they are now applied to prices. At present, a firm legally can increase advertising expenses by an amount which if used to lower prices would be considered predatory.

I agree with those who recommend action to deal with dominant firms, tight oligopolies, and the growth of conglomerate power. Actions to weaken substantially the advertising weapon of such firms would remove one leg on their four-legged stool. Divestiture is an obvious remedy that has proven largely unpalatable to the courts and legislatures. An alternative that has proven workable in a Canadian food-retailing case is to limit the growth of powerful firms by placing a ban on mergers, limiting their growth in capacity, limiting the rate of advertising, forbidding saturation advertising to deter new entrants, and banning geographic price discrimination. U.S. antitrust agencies may need new legislation to take such actions.

Finally, we have been guilty of tunnel vision in dealing with policies toward competition. If the behavior of an industry cannot be policed adequately using traditional antitrust policies, our tendency is to impose a layer of more specific controls, reports, inspections, licensing, etc. The Packers and Stockyards Act is a case in point. Although the effects of this Act appear to have been pro-competitive, modern technology suggests an alternative—the development of electronic exchanges for livestock. Through the broadening of markets and the anonymity of participants, these exchanges substantially reduce the feasibility of manipulating markets. Most of the antitrust activities of P&SA could be eliminated. Other nontraditional "antitrust" approaches should similarly be considered.

Some may consider these as drastic proposals to restore competition to that part of our "dual economy" that seems to be beyond salvation to a competitive way of life. However, given the symptoms, something is needed beyond a slap on the hand and an admonition to "go and sin no more." If we are ready to stop playing the game of antitrust charades, perhaps it is time to challenge Parker Brothers "Monopoly" with a new entrant, "Competition."

References

Bain, Joe. *Industrial Organization*, 2nd ed. New York: John Wiley & Sons, 1968.

Connor, John M. "Competition and the Role of the Largest Firms in the U.S. Food and Tobacco Industries." U.S. Department of Agriculture, forthcoming.

Edwards, Corwin D. *Control of Cartels & Monopolies: An International Comparison*. Dobbs Ferry, N.Y.: Oceana Publications, 1967.

Galbraith, J. K. "Planning, Regulation and Competition." Hearings before U.S. Senate Select Committee on Small Business, 29 June 1967.

Goldschmid, H., H. M. Mann, and J. Weston, eds. *Industrial Concentration: The New Learning*. Boston: Little, Brown & Co., 1974.

Grant, Winston W., Dale L. Dahl, and L. Leon Geyer. "Federal Antitrust Policy and the U.S. Food System." NC117 monograph, forthcoming.

Kaysen, C., and D. Turner. *Antitrust Policy*. Cambridge, Mass.: Harvard Univ. Press, 1959.

Mallen, Bruce. "A Preliminary Paper on the Levels, Causes and Effects of Economic Concentration in the Canadian Retail Food Trade: A Study of Supermarket Power." Ref. Paper No. 6, Concordia University, Montreal, Quebec, Feb. 1976.

Marion, B. W., and T. Sporleder. "An Evaluation of the Economic Basis for Antitrust Policy in the Food Industry." *Amer. J. Agr. Econ.* 58(1976):867–73.

Marion, B. W., W. F. Mueller, R. W. Cotterill, F. E. Geithman, and J. R. Schmelzer, *The Profit and Price Performance of Leading Food Chains, 1970–74*. U.S. Congress, Joint Economic Committee, April 1977.

Mueller, W. F. "Antitrust in a Planned Economy: An Anachronism or an Essential Complement." *J. Econ. Issues* 9(1975):159–79.

Mueller, W. F., L. Hamm, H. Cook. *Public Policy Toward Mergers in the Dairy Processing Industry*. North Central Rgnl. Res. Pub. No. 233, NC117 Mono. 3, University of Wisconsin, Dec. 1976.

Mueller, W. F. "The Celler-Kefauver Act: The First 26 Years." A study prepared for the House Judiciary Committee, 1978.

Mueller, W. F., and R. T. Rogers. "The Role of Advertising in Changing Concentration of Manufacturing Industries." NC117 Work. Pap. 17, University of Wisconsin, May 1978.

National Commission on Food Marketing (NCFM). Technical Study No. 8, "The Structure of Food Manufacturing," and Technical Study No. 10, "Special Studies in Food Marketing," June 1966.

Neal, P. D., ed. "White House Task Force on Antitrust Policy." BNA Antitrust and Trade Regulation Rep. No. 411, 27 May 1968, Part II.

Parker, R. C. *Comparable Concentration Ratios for 213 Manufacturing Industries Classified by Producer and Consumer Goods and Degree of Product Differentiation, 1947–63*. Fed. Trade Comm., March 1967.

Posner, Richard. "A Statistical Study of Antitrust Enforcement." *J. Law and Econ.* 13(1970):365.

Scherer, R. M. "The Posnerian Harvest: Separating Wheat from Chaff." *Yale Law J.* 86(1977):998.

Shepherd, Wm. G. *The Treatment of Market Power: Antitrust, Regulation and Public Enterprise*. New York: Columbia University Press, 1975.

Williamson, Oliver E. *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: Free Press, 1975.

Discussion

James M. Folsom

It is fortunate for me that there are two papers in this session. Considering that my disagreements with the Marion paper are substantially greater than with the Paul paper, I propose to use most of my time discussing Marion's work.

I am not nearly so pessimistic about the state of competition in food manufacturing as is Marion. Let me concentrate on three points. First, the decline in the number of food-manufacturing companies between 1947 and 1972 should not cause alarm in most food-manufacturing industries. Specifically, the 1947 Census of Manufactures reported 31,430 proprietors and firm members in SIC 20. The number was obtained by simple addition of the firms in each 4-digit category. If the more than 10,000 milk dealers and dairy product stores from the retailing census are added to the manufacturing firms, the total increases to about 42,000. The comparable number in 1972 is about 23,000 or a decrease of 19,000.

Averages can, however, be misleading. For that reason, I propose to look at the industries that account for the bulk of the decrease. Beginning with fluid milk processing, one finds just over 2,000 firms in 1972, or a decrease of more than 8,000 since the 1947 Census of Business. National 4-firm concentration fell from 22% in 1954 (the earliest year for which data are available) to 18% in 1972. At the same time, the importance of brands has diminished and advertising of trade names without prices probably has declined. It is my opinion that the industry has become more competitive.

Manufactured ice firms declined by almost 1,600 during the relevant period. Of course, sales fell by more than 50% even before adjustment for inflation as refrigerators replaced ice boxes and ice makers were purchased by restaurants and bars.

Butter manufacturers dropped by almost 1,300, but sales also declined even without adjusting for inflation. Top-4 concentration has increased to 45%, but the growth of margarine as a substitute reduces the significance of that number.

Table 1 shows the industries that experienced the largest declines in the number of firms. Only in one of those industries, beer, has the concentration reached a level that would concern most economists. And even there it appears that economies of scale could account for most of the increase in concentration.

Second, although some food-manufacturing concerns operate in a number of 4-digit industries, there are still a large number of single-industry firms. The 1972 Census of Manufactures shows 22,171 food manufacturing firms. The sum in the 4-digit industries is 23,325 and in the 3-digit, 22,794. Thus the maximum number of firms operating in more than one 4-digit food industry is 1,154 and in more than one 3-digit food industry is 623.

Third, although profits of food manufacturing have improved relative to all manufacturing, the picture is not as bleak as that painted by Marion. *Quarterly Financial Report* data show food-manufacturing profits exceeding all manufacturing by 6% 1971–75 and by 4% 1971–77. If 1975, which appears to be an anomaly because of the large profits made by grain trading firms, is excluded the difference falls to less than 1%. But my Malthusian tendencies lead me to believe that food never will again be the relative bargain that it was in the fifties and sixties. The growth of world income, which has increased the demand for food, precludes that occurring again.

Moving to food retailing, Marion is correct in stating that chains (eleven or more store firms) have increased in importance. To the extent that this has allowed firms to achieve real economies of scale, it is socially desirable. The more basic question appears to be whether national aggregates tell us much about the state of competition in grocery retailing. If, for example, one examines the ten largest food-retailing firms of 1962, he will find that three of them are not among the ten

---

James M. Folsom is now with Glassman-Oliver, Economic Consultants.

Table 1. Changes in Number of Firms in Selected Food Manufacturing Industries, 1947–72

Industry	Number of Firms			Top-4 Concentration		Value of Shipments ($ millions)	
	1947	1972	decrease	1947	1972	1947	1972
Manufactured ice	2,206	610	1,596	22	32	273	116
Bottled and canned soft drinks	5,169	2,271	2,898	10	14	748	5,454
Confectionary products	1,620	917	703	17	32	995	2,473
Bread, cake, and related products	5,985	2,800	3,185	16	29	2,404	6,132
Prepared feeds, n.e.c.	2,372	1,579	793	19	23	2,112	5,037
Flour and other grain mill products	1,084	340	744	29	33	2,527	2,380
Canned fruits and vegetables[a]	1,135	766	369	24	20	2,743	4,044
Fluid milk[b]	10,000	2,024	7,976	23	18	5,803	9,396
Ice cream	1,273	561	712	40	29	612	1,245
Creamery butter	1,482	201	1,281	18	45	845	808
Malt beverages	404	108	296	21	52	1,316	4,054
Totals	32,730	12,177	21,553				

Source: U.S. Department of Commerce.
[a] 1963.
[b] Estimated. There were 5,008 firms in 1958 when fluid milk processors were first included in the manufacturing census.

largest of 1976. Additionally, the largest firm of 1962 experienced a real sales decline after adjustment for inflation. Four of the ten largest firms in 1962 made less than 3% return on stockholder's equity in 1976, with two of them actually losing money. It seems unlikely that a "grand conspiracy" could continue to exist, if it ever did, with this diversity of growth and profitability rates. The more relevant questions are: (*a*) What has happened to concentration at the market level, and (*b*) are entry barriers sufficiently high enough for firms to earn persistent monopoly profits? Marion answers the first question. The second is too complex to address in the time allowed.

As to food wholesaling, additional concentration should have been expected as more and more chains take over the wholesaling function. But if we assume the nonchain retailers compete with chain retailers, the concentration number may not have great significance.

Perhaps I should, as Marion did, indicate that I am also not a dispassionate observer of antitrust. My self-image prevents me from admitting that fourteen years of my life are a charade. But I am concerned about entrenched positions of monopoly power and admit the failure of antitrust to deal effectively with them. This is of particular concern in some highly differentiated trademarked product areas. It is for that reason that Scherer's idea of licensing trademarks is attractive. There are, however, important trade-offs to be considered. A trademark conveys information to consumers. Will the competitive gains to consumers outweigh the value of the information lost? I believe it will in most cases, but I certainly cannot prove that.

The idea of royalty-free trademark licensing has an additional appeal if one is concerned about the level of advertising. The possibility of such action should reduce the incentive to advertise, resulting in a lower level of advertising expenditures.

In summation, antitrust has not proven effective in handling entrenched market power problems. It has, at best, resulted in a "holding pattern." New approaches and/or legislation are needed.

References

Scherer, R. M. "The Posnerian Harvest: Separating Wheat from Chaff." *Yale Law J.* 86(1977):998.

U.S. Department of Commerce, Bureau of the Census. "Concentration Ratios in Manufacturing." *Census of Manufactures, 1972,* pp. SR2-6–SR2-10. Washington, D.C., 1975.

Discussion

Lester H. Myers

The two papers presented are thoughtful and represent useful contributions to the body of professional literature. I will first comment on Marion's paper and then address Paul's paper.

Marion's paper focuses on the history of the use of U.S. antitrust laws to attempt to regulate the nature of competition in the food sector. Concluding that "antitrust policy to date has been incapable of dealing with some of the major competitive concerns in the food industry . . . ," Marion goes on to propose several changes which he feels will render antitrust policy and laws more effective.

In his initial suggestion for change, Marion pleads for more information flow, with which I agree. Recognizing the detrimental effect of concentration and conglomeration on public reporting of cost, price, and volume data, Moulton and Padberg evaluated the feasibility of mandatory public reporting of market information including relevant transfer prices in vertically integrated firms and line of business reporting by conglomerates. They argue that the real challenge is to weigh the possible technical efficiency associated with large firms and conglomerates against the cost of providing public information lost through mergers and/or vertical integration. This seems to pose a research dilemma because it is difficult to measure the efficiency advantage without complete cost, price, and volume information.

Relevant to the flow of information, Marion neglects to discuss the apparently important effect of antitrust laws and enforcement policies on limiting public disclosure of firm data. I know of several situations where major citrus-processing firms have used antitrust reasons for refusing to participate in voluntary cost surveys conducted by the University of Florida. It is ironic that the very laws designed to insure a competitive atmosphere can be used as a reason to retard the free flow of information so essential to the competitive model. Mandatory reporting could possibly overcome this problem but is politically unpalatable and expensive to enforce.

Marion argues hard for more control on media advertising expenditures. He is not alone. Parker and Conner suggest that "consideration be given to limiting advertising in industries where it is already intense . . ." (p. 20). I am not here to debate the social implications of advertising; however, I would like to make some comments based on our experience with Florida citrus.

I agree that the necessity for media advertising prohibits many firms from entry into the development and merchandising of national brands. The cost of a thirty-second prime-time network advertisement averaged $33,594 in 1976 and was expected to be 20% higher during 1977. Television networks have limited advertising spots to sell to a seemingly endless demand by advertisers because the cost per thousand households reached is still less for television than for other media. The results are rapidly increasing costs and network-imposed time-commitment conditions. As commodity groups increasingly assess the value of advertising, I believe it becomes more important for agricultural economists to evaluate the impact of television network advertising pricing and allocation decisions on barriers to entry and on competition. It may be that not only is more regulation needed regarding advertising copy and expenditures by the firms doing the advertising (as Marion suggests) but that more regulation is also needed on the "marketing policies" of the networks themselves.

In his section entitled price structure and time, Dr. Paul argues that time-price differentials may be useful indirect identifiers of the costs of specialized services needed to transfer commodities in form, place, and time. The concept has intuitive appeal and is no doubt useful in some cases, such as those cited in his paper. I would argue for caution here. Using his argument for determining the market price for frozen concentrated orange juice storage, I found, using spot prices as of 17 August 1978 and futures prices for September and November delivery as of 17 August, that the market

Lester H. Myers is professor of food and resource economics, University of Florida, and Economic Research Director, Florida Department of Citrus.

price for storage services was about 5.5¢ per pound of orange solids from August to September and minus 6¢ per pound from August to November. No concentrate is produced from oranges during this period although an official U.S. Department of Agriculture (USDA) crop estimate is released in October. Hence, it seems to me that Paul's method for estimating the price for marketing services implies a perfectly competitive market structure and stable, well-known supply and demand conditions. One might consider an underlying assumption of perfect competition rather interesting for a paper addressing the "problems" of research into competition in agricultural markets.

As I interpret his paper, Paul argues for extreme care when evaluating the information embodied in a reported price. Concerning time-price differentials, he asks: are the services needed to transfer products over time and their prices adequately defined? With respect to price discovery, Paul suggests that changing and incomplete market information may result in iterative pricing processes. Thus, the fact that price fluctuates frequently does not necessarily imply the lack of an equilibrium price or the failure of movement toward an equilibrium price. My concern is that if it is possible to define an equilibrium" price, it may only be possible to do so for such short periods of time and in such limited markets that the exercise becomes fairly academic. If this is true, we are then faced with the dilemma of evaluating pricing efficiency without the benefit of an observable "standard."

Paul attempts to help us here by focusing on the prices of services needed to carry products over time and on the careful definition of market boundaries. His comments are useful and thought provoking. A more complete exposition could, however, include the addition of market information uncertainties. How well are supply and demand changes anticipated by the firms engaged in reaching pricing decisions for current and future delivery? Perhaps what appear to be pricing anomalies actually reflect imperfect information flows and market uncertainties. The pricing of frozen concentrated orange juice following the January 1977 freeze certainly demonstrated an iterative groping behavior until better information became available concerning available supplies and the nature of demand at higher consumer prices.

Paul's concern over observed prices and what they measure reflects a growing concern among agricultural economists over reported prices and the information upon which pricing decisions are made. Witness, for example, the recent symposium entitled "Pricing Problems in the Food Industry" held in Washington and sponsored by NC 117. The dialogue is welcome and should stimulate interesting and fruitful research effort among agricultural economists.

References

Moulton, Kirby, and Daniel I. Padberg. "Mandatory Public Reporting of Market Information." *Marketing Alternatives for Agriculture: Is There a Better Way?* Nat. Public Policy Educ. Comm. Pub. No. 7, Cornell University, Nov. 1976.

Parker, Russell C., and John M. Connor. "Estimates of Consumer Loss Due to Monopoly in the U.S. Food Manufacturing Industries." Contributed paper, AAEA annual meeting, Blacksburg, Va., 7–9 Aug. 1978.

Discussion

Albert J. Ortego, Jr.

As I reviewed the papers of Paul and Marion, I immediately looked for ways to tie the two topics together. Paul's paper was stimulating to one who has been away from academic agricultural economics for ten years. While his subject matter is controversial, the paper is not. He pretty well protects all flanks. Bruce Marion's paper appears to be a plea for restoration of "competition" in the food industry or in the economy in general. The basic problems raised by Paul are the heart of the concerns raised by Marion in several areas of antitrust policies.

I want to make some brief comments relative to Marion's concern for advertising. While there are interrelated trends in concentration, acquisitions, conglomeration, and advertising, the direction of any causal relationship is certainly not clear. For example, it cannot be concluded that the strong positive relationship between television advertising and concentration indicates that advertising leads to concentration. It may be that concentrated industries find advertising more appropriate. It could be that the two are associated through some third factors or conditions that prevail in the product or its market. Further, that advertising is greater in the consumer goods industries is not surprising. Producer goods are more appropriately moved through market channels by personal contact and contractual arrangements. Hence, care should be taken when attaching any significance to differences between these two classifications.

The general policy of the antitrust laws, regulations, and enforcement is (or should be) to protect the consumer from business conduct which reduces social welfare. Paul points out that both the "Bressler-school" and "industrial organization" economists rely on partial equilibrium theory to determine the social cost of market imperfections. Marion indicates that antitrust policy is a "piecemeal" policy. In "The General Theory of Second Best," Lipsey and Lancaster show the futility of "piecemeal welfare economics." They point out, "To apply to only a small part of an economy welfare rules which would lead to a Paretian optimum if they were applied everywhere, may move the economy away from, not toward, a second best optimum position" (p. 17). The piecemeal antitrust policy of the United States must be based on value judgments that the policy will result in an increase in welfare or efficiency. But in an economy where there are many significant departures from conditions for a Paretian optimum, the theory of second best leads to the conclusion that there are, in general, no sufficient conditions for an increase in welfare. In short, in a situation where there are many constraints which prevent achievement of Paretian optimum conditions, the removal of any one constraint may affect the welfare or efficiency either by increasing it, by reducing it, or by leaving it unchanged. Hence, the U.S. antitrust policy is a piecemeal policy for which there are no a priori means of knowing whether a specific action will be good or bad, given the many other market imperfections that exist. The theory of second best raises serious questions from a theoretical viewpoint about our antitrust policies.

Marion points out, "There is a strong question whether existing legislation enables the antitrust agencies to challenge entrenched monopoly power" (p. 6). Grant this inability, and the entire antitrust policy becomes questionable. If market power is held by some market entities, then what is the basis for deciding that some entities should be denied market power or for deciding that they should be stripped of what market power they may possess? The possession of some degree of countervailing power is an essential condition for effective bargaining. To speak of arrangements, such as a farmer cooperative, for bargaining without some countervailing power is meaningless. Bargaining power involves the use of competitive influences to establish prices more favorable than those that would otherwise prevail. Bargaining power and market power (or monopoly power) are not the

Albert J. Ortego, Jr., is vice president for marketing, Dairymen, Inc., Louisville, Kentucky.

same: Market power extends over competitors on the same side of the market. However, bargaining power must be defined and measured relative to firms on the other side of the market. Yet, to speak of bargaining power with market power is meaningless. Countervailing power is more equitable and reasonable than trying to force one group to remain "competitive" when that group has to deal (either by purchasing from or selling to) with firms that have market power. Today, countervailing power is difficult to obtain. In my opinion, not only does antitrust legislation limit the ability to challenge entrenched monopoly power, but the entrenched power has the political influence to see that countervailing power is held down.

A retail grocery chain can enter into food processing and immediately, through its own stores, have captive outlets with ready access to consumers. Without control or ownership of numerous retail grocery stores, no other individual or group (including a producer cooperative) can go into food processing with an immediate volume of output (sales) that will permit low unit-processing costs. At one point, Paul raises the question, relative to grain firms involved in world markets, "How large must a firm be in each area to compete successfully?" In markets with vertically integrated food chains, a relevant question becomes: How does one obtain shelf space to gain access to consumers? The less differentiated a product, the more important this question becomes. Access to consumers through stores of a vertically integrated chain is virtually foreclosed. From observation and dealing with such firms, I know of cases where the total cost of getting products to consumers is increased through such vertical integration.

Again Paul raises the question, "How should one define an industry?" He goes on, "We usually say that it is all firms that make a single product; but then we must define a 'single product'." With the development of conglomerates, competition has shifted from a single product to competition for a set of products. The sale of a set of products certainly raises concern with the proper definition of an industry.

The relevant market discussions in antitrust cases center mainly on the geographic and product dimensions. Very little consideration is given to temporal aspects. Marion points out, "The fragility of market power carries important implications for antitrust policies. . . ." Yet, to my knowledge, no studies have been conducted relative to the conditions related to the maintenance and/or dissipation of market power acquired through mergers and acquisitions. Marion concludes, "As presently interpreted and enforced, the antitrust laws have had their greatest impact on maintaining fair and effective competition in 'commodity-oriented' industries which are structurally the most competitive, and where market power positions are the easiest to dismantle." Marion, as elsewhere, does not suggest methods for dealing with the problem. Relative to "fair and effective" competition, how can we evaluate as "fair and effective" that competition attained by maintaining (or attempting to return to) an atomistic structure on only one side of the exchange table?

In summary, I am really indicating a need for reexamining the total question of competition in this country. From a public standpoint, we need to set out the objectives of policies influencing competition—the desired economic intent and purposes. Then we must ask whether the existing economic structure and political environment will permit legislation, regulation, and enforcement of policies necessary to accomplish the desired intent. Failure to get major reforms in antitrust policies will probably continue our "piecemeal policy." Regrettably, because there is no way to determine a priori whether certain actions will improve efficiency or welfare, reduce it, or leave it unchanged, it is likely that antitrust enforcement will continue to be based on value judgments and greatly influenced by political pressures. Emphasis likely will continue to be placed on those areas that appear to be publicly supported at the time.

Reference

Lipsey, R. G., and Kelvin Lancaster. "The General Theory of Second Best." *Rev. Econ. Stud.* 24(1956–57):11–32.

Books Reviewed

Lappe, Frances Moore, and Joseph Collins. *Food First—Beyond the Myth of Scarcity*. Boston: Houghton Mifflin Co., 1977, 466 pp., $10.95.

Food First is an important book that deserves to be read widely for its perspective on the balance of world population and natural resources and for its insights into the economic and political processes that cause poverty and hunger. The main message of the book is that all nations could and should become self-sufficient in basic foods and provide an adequate diet to all of their citizens. The authors contrast the successes of Taiwan and China, which have largely eliminated the problem of hunger in spite of very dense populations, to Bangladesh and India, which have much more favorable ratios of population to land. Drawing upon information from all over the world, they conclude that there is no nation that could not eliminate the problem of hunger if it would make the distributive reforms that are necessary.

Because the authors believe that the extensive discussion of world population and natural resources diverts attention from the distributional issues, they have adopted a format to correct the misconceptions that center on scarcity. The title of each of the forty-eight short chapters is a question which reflects a common misconception about hunger and economic development. Some examples are: "Why Can't People Feed Themselves?", "What About the Real Basketcases?", "Haven't There Always Been Famines?", "Don't They Need American Corporate Know-how?", and "Aren't Poor Peasants Too Oppressed To Ever Change?"

In addressing the question, "Why Can't People Feed Themselves?" colonialism and its various modern-day residuals play a major role. Concentration of ownership of the best land by colonial elites, leaving the masses to the poor hillsides, is an easy case to make in most of Latin America. In Sahelian Africa the export orientation of agriculture is a residual of the colonial era. That the Sahelian tragedy was primarily a failure in distributive equity is summarized in the view that "every Sahelian country, with the possible exception of mineral-rich Mauritania, actually produced enough grain to feed its total population, even during the worst drought year" (Ganzin).

The book includes six chapters which describe the "Trade Trap" that poor agricultural nations get into when they attempt to develop on the basis of export crops. Because of heavy dependency on a few crops sold in competitive markets that are subject to volatile prices, trade balances are under heavy pressure for continual expansion of the export crops. Local elites have a particular interest in promoting exports to maintain the value of the currency to support luxury consumption. Multinational corporations receive harsh criticism for their role in this trade trap and also for creating wants for products that are useless for poor people and sometimes even harmful in total consequences, such as the case of substitution of baby formula foods for breast feeding.

After reviewing the now fairly widely known distributional impacts of high technology agriculture, *Food First* concludes: "In a real sense the idea that we are progressing is our greatest handicap" (p. 104). *Food First* also questions policies of the U.S.—USAID, military, and diplomatic—and their impacts on the likelihood of other nations making the reforms necessary to eliminate hunger.

The central theme of *Food First*, redistribution of access to resources, is necessarily controversial. This reviewer believes that the authors have built a strong case for their position, drawing upon more than five hundred sources. If the general tone of the book seems too radical to some readers, they should recognize that its conclusions are generally consistent with *Redistribution with Growth* (Chenery), which includes work of some of the World Bank staff. It also concludes that positive redistributive measures are necessary to alleviate the problems of poverty. By implication, "trickle-down" cannot be depended upon.

Writing from India and its development context leads this reviewer to one question not dealt with by *Food First*. It may very well be true that with the kind of distributive reforms advocated, India could adequately feed its total population. However, in view of population growth, widespread soil erosion, overgrazing, and in some places depletion of groundwater, a further question is how long it may continue to be possible. As it becomes less possible, it also becomes more difficult and less likely. Thus the longer-run issue of world population-carrying capacity remains largely beyond the scope of *Food First*.

Duncan A. Harkin
University of Wisconsin and
Tamil Nadu Agricultural University

Ritson, Christopher. *Agricultural Economics, Principles and Policy*. New York: St. Martin's Press, 1977, xii + 409 pp., $18.95.

Reading Christopher Ritson's book reminded me of an explanation by Lewis Carroll's Tweedledee. "Contrariwise, if it was so, it might be; and if it were so, it would be: but as it isn't, it ain't. That's logic" (Hyman, p. 92). The author, a young Turk among British agricultural economists, has written

a book on the principles of agricultural economics and agricultural policy that is mostly good and occasionally excellent, but is needlessly difficult in places, and sometimes tortuous. The book is ostensibly for intermediate undergraduate students who have previously imbibed an introductory economics course (courses usually last a year in Britain rather than a semester). This prerequisite is somewhat Pickwickian, unless the standards of my alma mater, which now employs Ritson, have comprehensively changed. Most graduate students will be challenged and stimulated at least by the book's latter half.

The book itself is divided into two approximately equal parts, the first dealing with the principles used in agricultural economics and the second with the analytics of agricultural policy. Each part contains four chapters. Part I outlines and discusses demand, supply, the market, and agricultural resource use. Part II introduces welfare economics and then presents a fairly detailed analysis of social cost benefits, agricultural trade policy, and concludes by dissecting some different agricultural support methods. Thus the first half of the book provides the tools for the second half which, mainly using the production possibility frontier, indifference curves, the isobudget line (or its equivalent), and demand and supply, concentrates solely on the public sector, usually emphasizing income distribution consequences. The author purposely excludes any discussion on farm management (I note rather ruefully that Ritson, along with the majority of his countrymen, still subscribes to Edmund Burke's philosophy that government is a continuance of human wisdom to provide for human wants).

The author emphatically states that one of his main goals is to apply theory. This, unfortunately, he does not do. His applications are almost entirely hypothetical, which will disappoint the reader who rightly expects more. Perhaps Ritson's main problem is that he relies exclusively on a geometric methodology (essentially Ferguson without the footnotes) and there are several discussion areas which cry out for some straightforward mathematics, making the points easier to grasp, simpler to apply, and probably clearer to present. Instead, we get convoluted diagrams reminiscent of those army maps which are only issued on night maneuvers. These diagrams occasionally require the "perhaps thirty minutes to one diagram" which the author suggests (p. iv), because they are complex, often require assumptions that are not stated, and because the reader must continually flip over pages or twist the book on its side to match the text with the diagram. The author would profit from his own approach by doing some substitutions on, say, a graph of knowledge isoquants plotted against geometric or mathematical inputs; or by recalling Haldane's dictum that an ounce of algebra is better than a ton of verbiage.

His first two chapters on demand and supply are basically well done. There is an excellent treatment of consumer income, and Gini coefficients and income distribution-demand curves are nicely incorporated, preparing us for his later emphasis on income distribution in Part II. Sadly, price flexibilities are ignored, though they seem to me a much more useful concept at the farm level than price elasticities. However, it is more surprising that he neglects the relationship between the aggregate demand curve for farm output, and farmers' total revenue, given its usefulness to the latter part of the book.

There are problems with the next two chapters on market mechanisms and agricultural resource use. In an attempt not to leave anything out, he tries to put everything in, thereby losing us among the trees when we should be looking at the woods. For example, we gain nothing by a three-paragraph presentation of the futures market (pp. 171–72), nor by a three-page digression into national income accounting (pp. 211–13), when the main subject areas are food manufacturing and distributing industries, and economies of size in farming, respectively. Such straying occasionally obscures a worthwhile analysis.

Part II of the book contains no history and is strictly analytical. Ritson argues cogently and convincingly in chapter 5 that a foundation in welfare economic theory is a basic requirement for studying agricultural policy. His main basis is what I take to be an adaptation of the classic Bator article, though no acknowledgments are cited. This is perhaps the strongest chapter in the book, marred only by an unnecessary three-page digression into the Scitovsky paradox. The ensuing chapter on social cost-benefit analysis is also good (Mishan fans will be pleased), and his discussion on the social preference rate is first class. The major problem in this chapter concerns his foundation diagram (fig. 6.1, p. 270) where private sector costs are assiduously tallied, but those of the public sector are ignored. Consequently, the benefits of public sector intervention are substantial (those who have followed British Labour Party economics in recent years will not be unduly surprised).

The chapter on agricultural trade policy is a veritable catchall. It is comprehensive, and most students will find it pretty hard going despite a benign beginning with a simple two-country trade model. He effectively destroys the concept of comparative advantage as the engine of international trade study and argues instead that government restrictions are the precursor. He follows with a good synopsis on exchange rates and inculcates us with the welfare effects of trade on agricultural self-sufficiency, tariffs, and the balance of payments and ends with an outline on some of the international commodity agreements.

The final chapter on methods of agricultural support starts by stating that income is the major objective of agricultural policy and then takes us through a remarkably complete list of policies which purport to do just that. These are succinctly classified

under measures reducing farm costs, those which increase farm revenue and, finally, structural policies. It does, however, tend to gloss over the fact that most have exacerbated the disparity in distribution of farm income. The weakness in this chapter lies in the conclusion, which is apparently taken from a colleague's journal article and contains insufficient information to decipher the essential diagrams. I get puzzled with graphs showing consumer surplus on one axis and producer surplus on the other, and no explanation as to who gains and who loses within the component producer and consumer groups.

The book does have some annoying features. The vast majority of diagrams and tables have no headings. Chapter 2 uses bushels, metric tons, English hundredweights, i.e., 112 lbs., and hectares, almost at random. Sources are sometimes ignored, apart from the author's colleagues, with whom the reader becomes very familiar, and some of the assumptions used in both synthesis and analysis are not stated. The book also initially may appear to have rather heavy European emphasis for American palates. But despite these features, this book is well worth buying. It will be particularly useful for faculty teaching an advanced undergraduate theory course in agricultural economics or basic graduate courses in welfare economics and agricultural policy. They will also profit by reading it solely for themselves. As John Wooden says, "It's what you learn after you know it all that counts" (p. 280).

P. J. van Blokland
University of Florida

References

Bator, F. M. "The Simple Analytics of Welfare Maximization." *Amer. Econ. Rev.* 47(1957):22–59.

Ferguson, C. E. *Microeconomic Theory*, 3rd ed. Homewood, Ill.: Richard D. Irwin, 1972.

Hyman, Robin, ed. *Quotations*. London: Pan Books, 1962.

Peter, L. J., ed. *Peter's Quotations*. New York: William Morrow & Co., 1977.

Rossmiller, George E., ed. *Agricultural Sector Planning: A General Simulation Approach*. East Lansing: Department of Agricultural Economics, Michigan State University, 1978, xvi + 430 pp., $15.00, $8.00 softbound.

This is a set of interrelated essays and reports by sixteen contributing authors who were members of Michigan State University's Korean Agricultural Sector Study team. It reports on an ambitious systems analysis and simulation modeling project carried out from 1971 through 1977. This effort expanded upon a framework of models and analyses begun in an earlier Michigan project in Nigeria. Both efforts were funded by the U.S. Agency for International Development.

Agricultural Sector Planning will be of interest to several audiences. The practical discussions of systems analysis and simulation model building will be useful not only to practitioners of these arts, but also to students, public officials, and decision makers who wish to learn more about them. The book should be especially helpful to those trying to decide whether or not to support or engage in large-scale model building efforts. Others will be attracted to the discussions of the philosophy of applied research and research methodology. Finally, the book will interest those who want to broaden their understanding of agriculture's role in national development.

Two of the opening essays are worth special mention. "Values and Policy Choices in Agricultural Development" (chapter 3), by Rossmiller and Johnson, is a skillful statement of how the many objectives of development can come into conflict, given available policy instruments. "Theory and Practice of Model Building" (chapter 4), by Manetsch, is a good introductory survey to this topic, one which includes such practical information as rules of thumb on the costs and capabilities of alternative model types.

Most of the book is devoted to descriptions of the actual models and model-building procedures developed by the Michigan State University team in Korea. Here the authors rely heavily on narrative description, providing a minimum of mathematical detail and only representative test runs and findings. Comprehensive technical documentation is recorded in a set of six companion volumes available separately. (This set, jointly entitled *Korean Agricultural Sector Model Technical Documentation*, contains approximately 1,200 pages and is available from the Department of Agricultural Economics at Michigan State University for $40.00. Computer documentation and sample output are included.) Nevertheless, the description provided in the book is usually complete enough to provide a reasonable understanding of how the five main subcomponent models (Population, National Economy, Technology Change, Resource Allocation and Production, and Demand-Price-Trade) are constructed and to permit some conclusions about major strengths and weaknesses. The following discussion covers a few of the highlights of the five submodels.

While Population, outlined in chapter 6 by Carroll and Sloboda, and National Economy, chapter 7 by Abkin, are understandably treated in less detail than components dealing more directly with agriculture, they cover familiar ground and appear to be reasonably complete. Population employs the cohort survival techniques for aging; for example, it computes agricultural labor as a residual of the labor demands of all other sectors, and it also uses nonagricultural labor demand as one means of

projecting rural urban migration. National Economy uses a sixteen sector input-output matrix as a way to account for the economy as a whole, and especially to deal with nonagricultural production. The I-O coefficients for the fifteen nonagricultural sectors are treated as fixed, whereas those for agriculture are changed on the basis of input use projections made in the subcomponent models for agriculture.

Technology Change, as described in chapter 8 by Lee, accounts for the impacts of likely land improvement projects and for the yield augmenting effects of increases in conventional input use (chemicals, fertilizer labor). However, only one type of innovation is allowed for in the model: step increases in yield, such as might derive from biological research. There was evidently no attempt to explore the possible implications of new or shorter-season crops, altered crop rotations, or mechanical innovations.

Resource Allocation and Production, covered in chapter 9 by Bauersachs and de Haen, employs a linear-programming approach in which parameters for the objective function and the resource constraints are periodically updated according to revised profitability and resource availability calculations. Constraints representing the riskiness of alternative cropping choices are incorporated to reflect farmer behavior under uncertainty. In general, the quality of this component appears to be high; certainly the quality of the mathematical exposition of chapter 9 is well above average for the book.

The Demand-Price-Trade component, described in chapter 10 by Teigen and Abkin, achieves an admirable balance between theoretical appeal and modeling pragmatism. For example, the modelers were able to use a system of demand equations which satisfy the homogeneity conditions of consumer demand theory. On the other hand, they found it necessary to assume constant partial derivatives as a basis for the substitution between goods in demand. While constants are also used for income elasticities, these are adjusted downward as consumption levels approach preset "targets" or satiety levels.

In addition to descriptions of model structure, the book provides an assessment of the extent of use of the models by the Korean Ministry of Agriculture. While the project was evidently successful in developing models, it appears to have been less successful in terms of the institutionalization of their use within the regular decision making processes of the ministry (chapter 18).

Simulation modeling as applied to the problems of agriculture in developing countries is an art which is still in its infancy. The Michigan State University projects clearly have advanced the state of this art. It is the contention of the authors of *Agricultural Sector Planning* that the basic structure of the model components which they have developed in Korea can be readily adapted for application to the problems of other developing countries. Time will tell whether or not this conviction is well founded. In any case, the way in which they have chosen to document their experience is commendable. Certainly, those considering whether or how to apply simulation techniques to the sectoral level problems of agricultural development would do well to consult this book.

James B. Fitch
The Ford Foundation, Cairo

Schmid, A. Allan. *Property, Power, and Public Choice*. New York: Praeger Publishers, 1978, xiv + 316 pp., price unknown.

In his appropriately titled book, *Property, Power, and Public Choice,* Allan Schmid adds another volume to the growing literature on the impact of institutions on total output and its distribution. The central theme of the work is that scarcity implies conflict and that resolution of conflict requires the assignment of power. The book opens with a Charles Russell painting depicting a cowboy and Indian "bargaining" over the passage of a herd on a long drive. With respect to the Indian's cutting a cow from the herd Schmid asks, "Is it theft? A prize of battle? Or is it a gift or act of charity? Does the cow represent the payment of a tax to a sovereign with the Indian as tax collector? Or has a trade been consummated where the Indian has agreed to allow passage and use of his land in return for a negotiated rental payment?" (p. xi). The question is who gets the power? There is a range of possible power assignments of which markets and government are only two. But, common to all of the alternatives is the fact that any assignment of power involves a public choice and that one party's opportunity set is another's opportunity loss.

To develop this central theme, *Property, Power, and Public Choice* is divided into five parts. The first section develops Schmid's theory of property rights. The second illustrates the variety and degree of interdependence within any power system. The third section provides the best statement of Schmid's paradigm, but the reader is left wondering why it was necessary to wait until the middle of the book to give this clear statement. The fourth section of the work claims to offer "rules for choice among alternative institutions." Unfortunately, it is the most disappointing of all, for Schmid's paradigm hardly provides any "rules for choice," leaving the reader wondering if there is any way to choose. Empirical institutional studies comprise the final chapter.

Schmid is to be commended for his challenge of the neoclassical market models and their implications. *Property, Power, and Public Choice* provides an excellent coverage of the literature on property rights and institutions. In reviewing this literature Schmid makes us fully aware of the pitfalls in neo-

classical analysis. His continual insistence that "one person's right is another's cost," that externalities are "ubiquitous," and that markets do not avoid these externalities makes it difficult for even the strongest holder of the faith to read the book without considering the normative aspects of the neoclassical paradigm. This is perhaps the book's major contribution.

Unfortunately, *Property, Power, and Public Choice* provides no alternative analytical framework. If the text were better organized, perhaps it would be possible to discern more positive hypotheses from the paradigm. But even if the organization were improved, this work does not provide "a theory to guide empirical study of the link between the rules of the game and the performance of the economy—amount, kind, distribution of welfare" (p. xiii), nor does it succeed in showing where the standard neoclassical approach to institutions is incorrect. In order for the Schmid paradigm to constitute a theory, it must provide some testable hypotheses which cannot be found in the first 252 pages of the work. The last chapter on "Empirical Institutional Studies" does contain such hypotheses, but it appears that they come from the standard neoclassical approach rather than from the paradigm Schmid tries so hard to develop.

Schmid accuses the neoclassical economists of attempting to "theoretically legitimatize a particular institution," but in this work he appears to be more concerned with theoretically "illegitimatizing" a particular institution, namely the market, than with developing a theory. It is true that in the market there are pecuniary externalities as well as technical and political externalities and that neoclassical analysis accepts the former but not the latter. Schmid continually insists that this is normative because "market coercion" affects the distribution of income (pp. 173–76). "A's income is affected by rights that influence both the tastes and income of others" (p. 59). To be sure all three types of externalities do have distributional impacts, but all three do not have the same effect on output. Pecuniary externalities ensure or encourage those actions which increase the size of the pie. It is true that not all actions will leave everyone with a larger piece, but all actors will have incentives which promote positive sum games. If it is wrong for economists to overemphasize efficiency, it is no more correct to overemphasize distribution. To make positive statements about efficiency, it is necessary to accept a status quo starting point. Schmid is unwilling to make this acceptance and provides no adequate basis for choosing any other point. It is perhaps for this reason that his efforts to develop a new theory and paradigm fail.

Terry L. Anderson
Montana State University

Rhodes, V. James. *The Agricultural Marketing System*. Columbus, Ohio: Grid, 1978, xiv + 430 pp., $19.95.

The agricultural marketing text by Rhodes is conventional in some aspects, yet different in others. The conventional aspects of the text include discussions of the entire agricultural marketing system in terms of the exchange, physical, and facilitating functions. Beyond this point the text differs from the conventional undergraduate agricultural marketing text. It differs because of the perspective of the system taken by Rhodes, the inclusion of topics not in conventional texts, and the framework used in analyzing the marketing system.

The marketing system for agricultural products as viewed by Rhodes is composed of agribusiness firms which face differing options depending upon their economic position. He explains how firm behavior actually molds, and to some extent directs, the marketing system through the procurement activities of these agribusiness firms. Rhodes states, "If it were not for tradition, it might be more accurate to title this text, The Agricultural Procurement System" (p. xiii).

Rhodes uses the Bain-Mason approach of market structure, conduct, and performance in describing the various marketing channels through which agricultural commodities flow. The process and institutional arrangements affecting these flows, and the methods employed by the firms which comprise the various channels are discussed. These descriptions are inclusive of the processing, wholesaling, and retailing sectors. The latter also includes the food service industry.

In discussing the marketing system and the agribusiness firms which comprise it, the emphasis is placed upon applied microeconomic theory of the firm and the managerial aspects of marketing. This micro-level analysis of the options available to the management of agribusiness firms in the marketing system is unique among contemporary textbooks dealing with the subject.

Rhodes refers to this blending of the managerial aspects and applied economic theory as his integrated framework of analysis. His treatment of various marketing topics within this integrated framework should not be an unfamiliar point of view to agricultural economists. In fact, Rhodes should be applauded for attempting to bridge the gap between marketing and management in the agribusiness area. These subjects traditionally have been treated as separate entities in the literature as well as in the classroom.

The major limitation of the integrated framework used by Rhodes is the state-of-the-art in neoclassical economic theory concerning firm behavior under oligopoly or monopolistic competition market conditions. The level of indeterminacy of firm behavior in these market models, resulting from the

interdependence in the decision making of the various firms, makes it extremely difficult to develop a rigorous framework of analysis. Despite this difficulty, Rhodes does describe how firms have differing pricing, product, and promotional (advertising) policies under different market conditions.

Rhodes assumes that the reader (student) has had a previous course in the principles of economics. While making such an assumption is the prerogative of the author, it would be extremely beneficial if the reader had an intermediate microeconomic theory course which includes the basic tenets of oligopoly and monopolistic competition. Such a background is needed to appreciate fully the description of firm conduct in the text. It might be argued by some that an introductory course in agricultural marketing would be beneficial if the reader is to glean and fully appreciate the material contained in the marketing text by Rhodes.

The text is current and capitalizes on the knowledge Rhodes has of agricultural marketing. It concludes by discussing current policy issues such as consumer interest, farm policy, maintaining competition in the marketing sector, and who will control the production resources in agriculture. These topics needed to be addressed in this marketing text because of the role agribusiness firms play in molding and directing the system according to Rhodes. Thus, the question surrounding such an influence on consumers, farmers, and society as a whole needed to be addressed.

Overall, the book is well written and suffers from only minor omissions and errors. It should prove to be a significant contribution to the literature in the area of agricultural marketing. The text does not leave the reader with the impression that the marketing system is in a quiescent state. In fact, the reader will envision the system as a dynamic and progressive sector of the economy which deserves further study.

Raymond J. Folwell
Washington State University

New Books on Agriculture

FOOD FROM THE SEA: THE ECONOMICS AND POLITICS OF OCEAN FISHERIES

Frederick W. Bell

Explores the past, present, and future use of living marine resources as an important source of protein, integrating biological, economic, and political principles.

380 pages hardcover, $25; paperback, $12

U.S. FOOD: MAKING THE MOST OF A GLOBAL RESOURCE

David W. McClintock

Focuses on a basic dilemma inherent in the development of U.S. agricultural policies: many of the best short-term options are the worst ones and vice versa.

ca. 150 pages ca. $15

PROTEIN, CALORIES, AND DEVELOPMENT: NUTRITIONAL VARIABLES IN THE ECONOMICS OF DEVELOPING COUNTRIES

Bernard A. Schmitt

Traces the circular relationships between nutrition and human capital, labor productivity, food production, and per capita consumption of calories and protein.

ca. 250 pages ca. $16.50

RICE IN THE TROPICS: A GUIDE TO THE DEVELOPMENT OF NATIONAL PROGRAMS

Robert F. Chandler, Jr.

Describes the research and technology responsible for increasing rice production in tropical and subtropical countries and outlines promising current research.

ca. 250 pages ca. $18.50

FOOD, POLITICS, AND AGRICULTURAL DEVELOPMENT: CASE STUDIES IN THE PUBLIC POLICY OF RURAL MODERNIZATION

edited by **Raymond F. Hopkins, Donald J. Puchala,** and **Ross Talbot**

Substantiates the assertion that political rather than technical factors hold the key to improved agricultural and economic development.

ca. 225 pages ca. $17.50

American Journal of Agricultural Economics

Volume 61 Number 2

May 1979

AAEA Annual Meeting
Washington State University
Pullman, Washington
29 July–1 August 1979

The *American Journal of Agricultural Economics* is published five times a year (February, May, August, November, December) by the American Agricultural Economics Association. Prior to 1968, this *Journal* was the *Journal of Farm Economics.*

Printed for the AAEA by Heffernan Press, Inc., Worcester, Massachusetts, USA.

Second class postage paid at Lexington, Kentucky, and additional mailing offices, Pub. No. 019500.

Editorial Policy

The purpose of the *Journal* is to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscripts should have a relationship to the economics of agriculture, natural resources, or rural and community development. Contributions, methodological or applied, in the business, extension, research, and teaching phases of agricultural economics are equally encouraged.

Editorial Communications

All manuscripts and editorial correspondence, except as noted below, should be addressed to the editor, V. James Rhodes, Department of Agricultural Economics, Mumford Hall, University of Missouri Columbia, MO 65211

Communications concerning book reviews and books submitted for announcement in the *Journal* should be sent to the book review editor, Herbert H. Stoevener, Department of Agricultural Economics, Oregon State University, Corvallis OR 97331.

American Journal of Agricultural Economics

Volume 61 Number 2

May 1979

Articles

Notes

Publications

Books Reviewed

Articles

Grain Marketing Systems: The Case of the United States versus Canada

Alex F. McCalla and Andrew Schmitz

This paper compares the U.S. and Canadian grain-marketing systems, emphasizing wheat. The historical evolution of each system is first presented; then each system's performance is evaluated using such criteria as producer prices and export market shares. The particular marketing system by itself is not the only determinant of performance differences of the two systems; government policies also play a role. Furthermore, the two marketing systems do not operate independently of each other. Often the Canadian Wheat Board uses the private system in the United States to carry out the delivery of grain once sales have been made; also, at times, the Board has made direct sales to U.S. grain firms.

Key words: grain-marketing systems, export and price performance, system interaction.

Public debate regarding the character of a country's grain-marketing system and the appropriate role of government in it has escalated in recent years in both Canada and the United States. In the United States the debate has focused most recently on two issues: (*a*) honesty in grading and (*b*) whether, in a world of state traders, U.S. reliance on a few, large, multinational grain-export firms is in the best interest of U.S. farmers, consumers, and taxpayers. Discussions of both issues have led to proposals for increased (or, in the case of grading, actual) government involvement in the grain-marketing system. In Canada a public debate is also occurring in a somewhat opposite direction—namely, should there be greater involvement of the private sector in a marketing system which, since the 1930s, has been dominated by a public monopoly, the Canadian Wheat Board?

In the current debates the following issues arise: (*a*) the level and stability of producers' prices and returns; (*b*) marketing efficiency, marketing margins, and returns to market intermediaries and middlemen; (*c*) physical capacity of the system, grain marketing investment and innovation, and the capacity of the system to respond to changing market conditions; (*d*) export performance; (*e*) equity to producers; and (*f*) the appropriate mix of public and private actors including, in particular, the role of multinational grain companies in both countries.

Participants in the debates in both countries often use the other country's system as a positive or negative example. Such a comparison on the surface appears reasonable, given that some policy proposals suggest increased similarities between the two systems. But is it a valid comparison to make? And if it is, what are the "marketing systems" being compared? Finally, what policy analysis tools are available to compare the performance of marketing systems?

It is these questions that we attempt to address in this paper. National policies evolve in the context of the social and economic development of a country. Further, every policy change involves, by definition, some gainers and some losers. Policy analysis, therefore, has a strong welfare focus. The approach to the issues involved in the evaluation of a marketing system begins by defining a marketing system in a comprehensive fashion. Then the nature of the marketing task in both countries is briefly outlined. In the next major section of the paper we present a detailed review of the current nature of each country's marketing system giving attention where appropriate to

---

Alex F. McCalla is a professor of agricultural economics at the University of California, Davis, and Andrew Schmitz is a professor of agricultural and resource economics at the University of California, Berkeley.

Giannini Foundation Paper No. 520.

The authors wish to express their appreciation to two referees for insightful and helpful comments.

the historical origin of major elements. Not surprisingly, the nature of public involvement in each system is quite different. We then consider what economic analysis has to offer policy makers who must make future policy decisions. The findings suggest that, on the issue of performance, the tools are not very precise.

The "Marketing System"

It is important to define the marketing system because often elements of a marketing system, such as the Canadian Wheat Board (Board), are identified as the "total system." For purposes of this paper, a grain-marketing system includes all elements that influence—directly or indirectly—the movement, transformation, and price of grain once it leaves the farm of origin. These include: (*a*) the primary collection system of country or primary elevator delivery points; (*b*) the inland and port terminal systems which receive, store, clean, grade, and ship grain toward final destination; (*c*) the transformation system which mills, processes, and packages grain products for intermediate use (i.e., feeds) and final consumption (food products); and (*d*) the transportation system that moves grain and grain products between the functions described in (*a*), (*b*), and (*c*) above.

The above four elements are often defined as the grain marketing system, but, clearly, these are the elements of the physical system. There are, of course, additional elements. For instance, there is (*e*) the set of policies, public and private, which grade and certify standards of grain and grain products; (*f*) the institutions which facilitate the functioning of the system. In the private sector, these include elevator companies, millers and processors, cooperatives, multinational export firms, and the various commodity exchanges. In the public sector, these include government institutions such as the Federal Grain Inspection Service [U.S. Department of Agriculture (USDA)], the Commodity Futures Trading Commission, the Board, the Canadian Grain Commission, etc. (*g*) The public policy environment includes national farm policy regarding grain prices and acreages, export policy (exchange rates, export subsidies, two price systems, P.L. 480, etc.), and such other national policies which influence directly or indirectly the marketing of grain. (*h*) There is also the mechanism that establishes prices for grain at all points in the physical handling system. This mechanism is obviously influenced by public policy and marketing institutions.

This definition of the marketing system is somewhat broader than most traditional definitions (for example, Hill and Van Blokland). These categories are used later when the two countries' marketing systems are described.

The Grain-Marketing Task: The United States and Canada

Table 1 presents some comparative statistics on Canadian and U.S. grain production in terms of acreage, production, domestic consumption, and exports for all grains, wheat, and feed grains. Several factors stand out from the table. (*a*) Relative to Canada, the acreage devoted to grain production is much greater in the United States. (*b*) The number of important grain crops grown in the United States exceeds those grown in Canada. In Canada wheat is a dominant crop with barley a distant second. In the United States corn, soybeans, and wheat represent major crops. The geographic dispersion of production is also much greater in the United States. (*c*) The domestic market is of much greater importance to U.S. grain producers despite the fact that, in volume terms, the United States is a larger exporter of grain than Canada. Conversely, the export market, particularly for wheat, is much more important to Canada. (*d*) The grain consumption centers and export ports are much more geographically concentrated in Canada.

In terms of marketing patterns, Canadian grain is produced mainly in the western prairie provinces and is shipped largely by rail to both West and East coasts for domestic and export use. In the United States, grain moves from dispersed production areas to dispersed consumption and export points by a variety of transportation modes, including trucks, railroads, and barges. In view of the size of production and exports, diversity of crops, and the geographical location of production and consumption, the task of marketing U.S. grain is both larger and more complex than that in Canada.

Table 1. Production, Domestic Use, and Exports, United States and Canada, 1954–57, 1964–67, and 1974–77 Averages

	United States			Canada		
Years	Production	Domestic Use	Exports	Production	Domestic Use	Exports
	million metric tons					
Wheat						
1954–57	26.4	16.3	10.5	12.4	4.3	7.8
1964–67	36.8	18.2	21.2	18.2	4.2	12.5
1974–77	55.2	20.4[a]	28.8[a]	18.3	5.0[a]	13.1[b]
Feed grains[c]						
1954–57	110.3	98.0	7.3	10.4	8.5	2.1
1964–67	141.8	124.8	21.8	10.6	9.8	1.1
1974–77	182.3	130.5[a]	47.0[a]	14.1[b]	10.4[b]	3.8[b]

Sources: USDA *Agricultural Statistics, 1959,* 1960, and selected issues; USDA ERS *Agricultural Outlook,* AO-25, Sept. 1977, and selected issues; USDA FAS *Foreign Agricultural Circular: Grains,* FG-7-77, July 1977, and selected issues; Canadian Wheat Board, *Annual Report, 1965–66,* Winnipeg, Manitoba, 1967, and selected annual issues; and United Nations Food and Agriculture Organization, *Production Yearbook,* vol. 25, Rome 1971, and selected annual issues.

[a] Includes projections for 1977–78.

[b] Canadian data include 1974–76 average for production, domestic use, and exports.

[c] For the United States, includes corn, barley, sorghum, and oats; for Canada, includes barley and oats.

The Evolution and Current State of Grain Marketing Systems

In reality, a marketing system evolves in response to a sequence of policy issues which are dealt with within a particular set of conditions existing at that time. Thus, description of the U.S. and Canadian systems is presented in a historical frame. The functional elements outlined above are used; namely, the physical marketing system (elements *a–d*), the grading system (element *e*), the institutions (element *f*), the public policy environment (element *g*), and the pricing mechanism (element *h*).

Grain has been a central component in the development of agriculture in both countries. In the United States the major expansion of commercial grain growing occurred with the settlement of the Midwest, the Great Plains, and the West. Its most rapid expansion dates from the 1830s when the development of a network of railroads greatly facilitated the movement of grain. In the latter half of the nineteenth century, the United States became the largest exporter of wheat, which, in the 1890s, averaged 44% of world trade and a third of U.S. production (Davis, pp. 1–27). The dominance of the Unites States as an exporter waned in the 1930s, but she regained her dominant position in the 1960s and 1970s.

The development of a major grain economy in Canada evolved somewhat later; similarly, it was a function of the settlement of the Canadian prairies. This settlement and the resulting expansion of grain growing occurred following the completion of the Canadian Pacific Railroad in 1885 and other railroads which subsequently were built. Canada has been an important exporter of wheat throughout the twentieth century.

The Physical Marketing Subsystem

In the early years both systems consisted of primary grain delivery points which were privately owned by either elevator companies or railroads. Government involvement was limited. However, public policy issues soon arose in Canada regarding access to delivery points and the fairness of elevator and railroad companies. The Manitoba Grain Act of 1900 provided for regulation of grain dealers and also provided for increased competition at shipping points. This Act, which subsequently was revised to include boxcar allocation and grading, became the Canada Grain Act of 1912; it established the principle of fair access which has persisted as a major public policy objective in Canada.

Extensive development of farmer marketing cooperatives occurred in both countries in the 1920s. These cooperatives, as price bargaining enterprises, were unsuccessful and ended with the Depression. However, the ownership pattern of primary elevator points was altered by the experience, particularly in Canada. Thus,

in the 1970s there is a major difference between the systems at the primary elevator level. In Canada about 80% of the primary elevators are owned by cooperatives. The three wheat pools—Alberta, Saskatchewan, and Manitoba—own about 2,600 elevators, and the United Grain Growers own 743 out of a total of 4,300 (Canadian International Grain Institute). Further, in Canada, the Board and the Canada Grain Commission extensively regulate rates charged in country elevators for handling and storage, and they manage shipments from country elevators. In the United States the role of cooperatives is less extensive though growing. In the 1950s coops accounted for between 30% and 40% of marketings. Subsequently, the coop share of the grain elevator business has fluctuated between 40% and 46% (Hill and Van Blokland). Rates charged for handling and storage and the movement of grain from primary delivery points are not subject to government policy.

A second element of the physical handling system involves the system of inland and port terminals which provide consolidation of shipments and storage. In the United States this system is dispersed and has changed significantly with time. In the early 1900s terminal and storage facilities developed at the railheads with major concentrations occurring, for example, around Minneapolis and Buffalo. With changing demands and shifting transportation mechanisms after World War II, terminals developed at inland points, e.g., Chicago and Kansas City and at river and gulf ports. Throughout this evolution, the private sector has been the dominant participant even though the Commodity Credit Corporation (CCC) has greatly influenced the demand for storage capacity. In Canada a much more concentrated system of terminals developed primarily at the Lakehead and on the Pacific Coast. From the beginning, the Canadian government, through Canadian Government Elevators, has been involved. Further, the major cooperatives own substantial terminal capacity. Thus, in Canada the majority of terminal elevator capacity is in the hands of the government or the coops. Further, rates are regulated by the Canadian Grain Commission.

In both countries the transformation industry is in private hands and is largely without government involvement. The market structure of these industries—flour milling and feed transformation—is not fully documented but appears to consist of large and small firms with both very specialized and vertically integrated functions. There are two major differences between the two transformation systems. First, given the importance of the domestic market in the United States, the volume of activity in this sector is roughly ten times as large as that of Canada. Second, the importance of the feed industry in the United States is pervasive. This results from both the greater variety of feedstuffs grown and processed (e.g., corn and soybeans) and the large size of the U.S. livestock industry.

The fourth element of the physical handling system is the transportation network. In Canada the primary and dominant mode of transportation has been and still is the two transcontinental railroad systems—one privately owned (the Canadian Pacific) and one publicly owned (the Canadian National). Shipments to eastern and export markets have also used boat transportation on the Great Lakes during the summer months. Truck and river barge movements have been of limited importance unlike the United States, where these modes have provided an increasingly important alternative to rail shipment. It is argued elsewhere that the Canadian transportation and grain-handling system has not, at least until recently, exhibited the degree of technological innovation that the U.S. system has (Schmitz and McCalla 1976). This probably results from two dominant factors: (*a*) lower volumes and few profitable alternatives and (*b*) publicly set transportation rates. In particular, the Crows Nest Pass Rates on export grain have provided relatively low rates for Canadian grain shipments since 1897. The Crows Nest Pass Agreement was a *quid pro quo* with the Canadian Pacific Railroad Company in return for development rights in the Crows Nest Pass of Southern Alberta and British Columbia. This agreement guaranteed in perpetuity low stable rail rates on export grains. These rates apply to this day on export shipment on all railways (Kulshreshtha and Devine). In the United States rail rate control has also been in effect through the Interstate Commerce Commission but not to the extent of setting rates as an element of national grain policy. Further, barge rates have not in general been regulated, which has provided a competitive alternative to railways. Thus, major transportation innovations, such as unit trains and high throughput inland terminals, occurred first in the United States. These developments appear to have given the U.S. sys-

tem more capacity to respond to changing demands, particularly export demands, than has the Canadian system. Further, the system of boxcar allocation operated in Canada as a part of an equity access policy has involved public institutions (the Board and the Canadian Grain Commission) much more heavily in the transportation system in Canada (Schmitz and McCalla 1978).

Thus, a comparison of the physical grain-handling systems in Canada and the United States reveals some differences, particularly with respect to the mix of public and private activities. In the United States the physical handling system is dominantly a private sector activity with government playing a limited role except through general rail rate policy and intermittent impacts of public policy through the CCC on the demand for storage. In Canada cooperatives are more important in the primary delivery system, and coops—in conjunction with the Canadian government—dominate the storage and terminal subsystem. Further, rates for storage, handling, and transportation are elements of public policy as is the allocation of boxcars. Only in the transformation subsector is government in Canada not involved as a direct participant in grain handling and/or rate setting.

The Grading Subsystem

Grading of grain, particularly for export, has long been recognized as an important element of a grain-marketing system. Comparison of the two marketing systems reveals significant differences in approaches. As a response to farmer complaints, Canada implemented mandatory federal grading of grain under the Canada Grain Act of 1912. This Act designated the Board of Grain Commissioners (subsequently called the Canadian Grain Commission) as the federal agency to set standards and grade grain. Canadian federal grades became well recognized in international markets as valid and consistent measures of quality. Mandatory federal grading persists to the present as an integral part of the Canadian system. The United States established federal grades for grain under the Grain Standards Act of 1916. However, unlike Canada, the role of the USDA was to establish standards for grains moving in interstate and export trade and to license individuals or state agencies to do the actual grading. Thus, a major defect developed in terms of enforcing consistency in standards. A major scandal relating to grain grading emerged in the mid-1970s (U.S. Congress) which resulted in the Grain Standards Act of 1976. This Act mandated federal grading of grain for export and established the Federal Grain Inspection Service. Thus, more than sixty years after Canada established mandatory federal grading by government inspectors, the United States followed suit. At the moment the degree of public involvement is similar, though in the United States it will no doubt take time for the new system to outlive the weaknesses of the past system.

Institutional Pricing and Public Policy Dimensions

The physical and grading subsystems described above operate within the context of a broader set of institutions, public and private. In addition, public policies create an environment within which a marketing system operates to move grain and establish prices. It is to these elements of the grain-marketing system that attention now turns. Given that the Board is often identified as the marketing system in Canada, its evolution and current role are reviewed in some detail to show clearly how it fits into the system. Next, the U.S. system is discussed briefly, and this section concludes with a discussion of public policies and their influence on pricing.

The Board was first established during World War I. As a result of a centralized Allied purchasing agency, a centralized selling agency—the Board of Grain Supervisors—was established in Canada in 1917. Between September 1917, and July 1919, the Board of Grain Supervisors was the sole marketing agency for Canadian grain and was authorized to fix prices and regulate sales. At the end of the war, uncertainty in the world market caused the Canadian government to establish the first Canadian Wheat Board, which operated on an initial payment and final pooling basis. However, it was clear that the intent of the Canadian government was not to get into the grain business, and the Board lapsed after functioning for the 1919–20 crop. The return to normal trading in the Winnipeg Grain Exchange coincided with rapidly falling prices in the world market. Despite the fact that there was probably no cause-effect relationship between the change in marketing systems and falling prices, "farmers themselves . . . were

convinced that the opposite was the case and the goal of a central marketing system became the focal point of the rising agrarian protest movement in the 15 years that followed" (Treleavan).

Having failed to obtain a government marketing pool, prairie farmers turned to cooperative pools—the Alberta Wheat Pool, Saskatchewan Wheat Pool, and Manitoba Pool Elevators—which by 1929 had over half of Canadian grain under contract. The Pools banded together to establish a Central Selling Agency which marketed directly in domestic and international markets, bypassing the traditional markets. In 1929 the Pools offered an initial payment which soon was substantially above market prices. They attempted to hold grain as prices continued to fall, bringing the Pools to the verge of bankruptcy. The three provincial governments guaranteed their loans in the 1929 crop year; but, when the same situation occurred in 1930, the federal government guaranteed the loans and appointed a manager to run the Central Selling Agency. By 1935, most of the stocks accumulated by the Pools had been disposed of, and the federal government again tried to get out of the grain business. However, farm pressure led to the establishment of the second Board as a voluntary alternative for farmers when the free market was reopened. Essentially, it was the same as the Central Selling Agency with government-guaranteed credit. As such, it did not represent a radical departure from previous years.

During the years 1935–38, Board prices were generally below market prices, and the Board did not play a major role in the market. In 1938–39, however, world prices fell, and the Board bought the entire crop. World War II ensued and, in 1943, as a wartime measure, the Board was made a mandatory monopoly marketing agency for prairie wheat moving in interprovincial and international trade. In 1949, barley and oats were added to the Board's authority mainly as a result of western farmer pressure. In 1967 the Board was made a permanent Crown Corporation. The authority of the Board remained essentially unchanged until 1 August 1974, when western farmers were allowed the option of selling feed wheat, oats, and barley for nonhuman consumption in Canada through the open market. The Board has jurisdiction only in the three prairie provinces plus the Peace River area of British Columbia, and it regulates only interprovincial and international movement of prairie grain.

The Board's mandate is: "(1) To market as much grain as possible at the best price that can be obtained; (2) to provide prairie grain producers with price stability; (3) to ensure that each grain producer gets his fair share of the available markets each year" (Canadian Wheat Board).

To meet its mandate, the Board uses a pooled-pricing mechanism and a delivery quota system. The pooled pricing system involves (*a*) an initial payment which is paid when the producer delivers his grain to a primary elevator—it is set by the Canadian government usually at the suggestion of the Board and is a government-guaranteed price to the producer—and (*b*) a final payment based on proceeds from crop-year sales minus Board and initial payment costs.

Through the price-pooling policy, the Board achieves price stability for grain marketed during any given crop year by prairie producers. All monies received by the Board from the sale (both domestic and foreign) of a particular kind of grain are placed or "pooled" in a single fund. For all grain sold through the Board, producers receive the same price (except for differences in internal transportation costs) for grain sold during a given crop year regardless of the particular day and month of sale. In the case of U.S. grain sold through the open market, there can be a great deal of variation among producer prices since these can fluctuate greatly from month to month, making the timing of sales very important in determining the prices received by producers.

The Board also has the power to (*a*) issue a permit book to all prairie producers who desire to sell grain (the producer delivery permit book system is used to operate the quota system); (*b*) limit grain deliveries to primary elevators by producers in possession of a permit book; and (*c*) fix, from time to time, quotas for each kind of grain that can be delivered to primary elevators. The quota system is used to achieve the Board's objective that each producer has an equal opportunity to sell his grain. This system controls the quantity, kind, and quality of grain (except for a portion of domestic feed grains) each producer can deliver at any particular time. The number of bushels a producer can deliver is determined by quota acres (producers' quota base) calculated for each farmer using a formula which includes land seeded to grain, oilseeds and

forage, and summer-fallow land. A producer may allocate any part of his quota base to the delivery of a particular kind of grain or all of it to one kind. The number of acres assigned to each grain determines the quantities of that grain the producer will be able to deliver to a primary elevator under quotas authorized from time to time. Through the quota system, the Board manages flows to the market and has at times forced producers to hold sizable inventories. These in turn could cause producers to reduce acreage; thus, the quota system can serve as an indirect means of regulating national output.

Thus, through pooled prices, quotas, and allocation of boxcars, the Board has a broad, direct involvement in the Canadian grain marketing system. However, it owns no marketing or transportation facilities. Rather, it contracts for these services with the national railroads and cooperative and private elevator companies. The Board's function, therefore, is essentially administrative.

Private grain companies (many of which have their headquarters in the United States) also play an important role in Canadian grain marketing. They can act as the Board's export agents. They can also purchase grains from the Board as principal, assuming the full risks of ownership and of finding foreign markets. Thus, the marketing system is not completely made up of the Board or private trade. However, the private traders do not buy the major export grains directly from producers.

The ability of the Board to manage the grain market comes from the authority given to it under the Canadian Wheat Board Act. To control the market, the Board controls the flow of grain through the country elevators by regulating the movement of all grains from primary elevators to domestic processing plants and export points. With the exception of special crops—such as mustard, buckwheat, and peas—the Board receives its authority to control transportation from the Canada Grain Act.

There are no institutions comparable to the Board and the Canadian Grain Commission in the U.S. grain-marketing system. The only government institution partially comparable to the Grain Commission is the newly established Federal Grain Inspection Service. The major functions of grain purchase, movement, transformation, and sale for both domestic and export markets are provided by private traders in the market. Studies of private market structure in the U.S. grain market are limited. However, what evidence there is suggests increasing degrees of concentration as grain moves toward the export market. Eighty-four percent of U.S. grain is delivered by its farmers to about 8,000 country elevators (U.S. Congress). Most of this grain is moved to 450 inland terminals and 80 port elevators (U.S. Congress). It is at this later point that concentration appears to exist. It has been estimated that the five largest multinational export firms handle 90% of U.S. grain exports and 70% of total world trade (Frevalds, p. 116). Part of that 70% is Canadian grain, where the same multinationals function as agents for the Board or buy grain directly from it.

Public policy also influences the performance of marketing systems. It is here that additional significant differences exist between the systems. In Canada public policy, with respect to the grain-marketing system, has occurred largely by creating the institutions already discussed which are directly involved in the marketing system. With the exception of price supports for feed grains grown outside the prairies and the special federal program, Lower Inventories For Tomorrow (LIFT), to reduce grain acreage in 1971, the Canadian government has not engaged in price- and income-support programs for the Canadian grain industry. While it is true that the Board's initial payment is a price guarantee, it has, with few exceptions, been set below "anticipated" market prices so that no direct transfer from the federal treasury has occurred (see Schmitz and McCalla, 1978, for exceptions). However, in the United States, federal price and income policies dating from the Agricultural Adjustment Act of 1933 have had significant impacts on the economic incentives for U.S. farmers to produce grain. Wheat and feed grain programs have been an integral part of U.S. farm legislation almost continuously since 1933 (Rasmussen and Baker; Cochrane and Ryan). These price-support programs coupled with demand-expansion programs, such as Food Stamps and P.L. 480, have clearly influenced the quantities of grain the U.S. system has marketed. In earlier years price-support programs functioning with loan rates based on parity or legislative mandate often resulted in prices above world prices necessitating extensive storage and export disposal through the use of export subsidies. Even the current program of target prices and loan rates involves the public sector in outcomes in the grain sector. In the Canadian

grain market, indirect government involvement has not been nearly of the magnitude as that in the United States.

Thus, when one turns to pricing in the two systems, a very complicated picture emerges. In Canada the Board has a pervasive influence on day-to-day prices and prices received by farmers. However, in general, the Board has attempted to price to move grain rather than function as an element of government policy to enhance grain growers' income. The existence of the Board has, however, rendered inoperative (wheat) or only partially effective (feed grains) traditional price discovery mechanisms such as futures and cash markets. The Winnipeg Grain Exchange does not trade wheat futures and trades limited volumes of feed grains. The market is active in non-Board grain. Thus, the Board—by functioning in the market—clearly influences prices.

In the United States, active futures markets exist in Chicago, Minneapolis, and Kansas City. However, price discovery in these markets is clearly influenced indirectly by U.S. agricultural policy. Further trading is monitored by the Commodities Futures Trading Commission. However, direct price formation is a function of private traders operating in the market.

Performance of the Two Systems

Economists have had great difficulty defining an aggregate norm for evaluating the performance of marketing systems. No objective, agreed-upon, single criterion of performance seems to exist. Generally, one of four approaches has been used: (*a*) the use of theoretical constructs; (*b*) the use of empirical welfare concepts (Currie, Murphy, Schmitz; Mann; Brandow); (*c*) the industrial organization approach (Bain), which has been recently criticized by both Jesse and Brandow; and (*d*) the historical, institutional, and descriptive approach (Goldberg, Caves). However, each contains elements that provide insights to particular issues relating to the performance of a marketing system. Therefore, a pragmatic, partial policy-analysis approach to evaluating market performance of the Canadian and U.S. grain-marketing systems is adopted using whatever tools seem most appropriate to the particular policy issue. Underlying these, of course, are theoretical propositions and relationships; but the purpose of the paper is to make a practical assessment in terms of some generally acceptable and significant criteria. There is the further advantage of doing comparative analysis. Jesse argues that comparative analysis need not wait for the development of an absolute norm.

The specific approach is to consider each policy issue outlined at the outset to see what can be said about the relative performance of each system. In most instances the policy issue has a counterpart in Jesse's expanded list of performance indicators. Definite conclusions are not reached as to which system is "best."

Product Quality and Grading

The mandatory federal grading system in Canada has a lengthy history as noted earlier. Canada has had and continues to have an excellent international reputation with respect to grading. It is commonly said that Canada's Certificate of Final Grade has the "integrity of a gold bond." As a result, Canada was for a significant period the only country to market grain successfully on the basis of a certificate of grade and weight (Canadian International Grains Institute).

As noted earlier, the United States has only recently adopted mandatory federal grading of export grain. The United States has also recently introduced a major change in grading to include protein content. Under "protein grading," prices are related to very fine calculations of protein content of various types of wheat. Thus, in the important area of product quality, it seems reasonable to conclude that the Canadian system has performed very well. In view of U.S. adoption of protein grading, it seems likely that Canada will have to follow suit. The U.S. system, as currently organized, has the potential for product quality consistency.

Producer Prices and Returns

The best test of the relative performance of each system in terms of producer welfare would be the relative profitability of grain production in each country. Such a comparison would involve not only price comparisons but also considerations of the two other factors in the profit equation—levels of production and costs. Yet, to our knowledge, such a comprehensive study has not been done. Therefore, the profit picture cannot be assessed a priori.

One can, however, comment on what is known about each of the components of profitability. Available data suggest that grain yields in the United States are consistently higher than in Canada. Part of this difference no doubt is due to more favorable climatic and agronomic conditions. However, policy also influences yields and the associated production costs. If, as often argued, Canadian grain policy through the use of acreage-based quotas has encouraged land-extensive production techniques—whereas U.S. acreage control has encouraged purchased input-intensive production techniques—one could reasonably expect per unit variable costs of production to differ between countries.

The question of prices has several dimensions: the absolute level of prices, the stability of prices and the associated issues of risk management, price discovery and the role of price in resource allocation, and the impact of policy on prices.

Several attempts have been made to compare producer prices in adjacent regions in the two countries. For example, a study published by the Canadian Pacific Rail concludes that farmer returns are similar but, because of lower Canadian freight rates, Canadian farmers are implicitly worse off. The study stops short of presenting definitive reasons for this apparent anomaly.

Table 2 presents a comparison of Canadian and U.S. wheat prices for the years 1955–77. The Canadian price is for No. 1 Red Spring grade. The U.S. price is the average price received for all wheats. Thus, the two are not strictly comparable. The expectation would be that the Canadian price is high relative to U.S. average wheat prices for all grades. When Canadian prices are adjusted for exchange rates (but not quality), the twenty-two-year average price is lower when program payments are included in U.S. prices but higher when program payments are not included. However, during the period 1963–74, the vast majority of U.S. farmers participated in wheat programs, making the former comparison more valid. In recent years Canadian prices have been consistently higher.

However, some additional points need to be noted. First, because of price pooling in Canada, all producers receive the same price for any given year except for adjustments in transportation costs. The price is the same regardless of the time of year when farmers actually deliver wheat to be sold (through the Board) to the country elevators. However, the prices received by U.S. farmers are not pooled; hence, some producers received higher prices than those listed in table 2 while others received prices below. A clear illustration of this is when Montana farmers benefited much more than did Texas producers during the price rises of 1973 because the large price rise occurred after the Texas harvest. Second, the U.S. price is an unweighted price, which is not the case in Canada; hence, the prices reported for the United States may be on the high side. This would be the case if the weighted-average price for wheat compared to simple average prices bears the same relationship as feed grain prices for which weighted averages are available (USDA). Third, during some of the years (especially in the late 1960s), not all wheat grown by Canadian farmers was sold through the Board because of tight quotas. Some grain was sold directly from farmer to feedlots at prices well below those given in table 2. Hence, for certain years, the profitabilility of wheat farming for Canadian producers was not reflected totally in Board prices. However, for the crop years 1973–74 to 1975–76, there were no quota restrictions in Canada; hence, the prices given generally showed a bias of the income position of farmers in the opposite direction to the "surplus" periods because stocks stored at the farm level during this period were sold at higher prices when open quotas prevailed.

Farmers also are concerned about price stability and risk management. It is clear from the nature of the Canadian Wheat Board that producers experience stable prices within crop years. The same is certainly not true in the United States. On the other hand, interyear price instability appears from the raw data to be comparable between the two countries. This is to be expected, given that prices in both countries are tied to the world market. Whether or not producers prefer a system whereby everyone receives the same price regardless of the time of sale—over a system where there is no single, pooled price—seems to depend largely on the type of commodity and the type of producer. For example, farmers who are relatively good at forecasting prefer price instability where the possibility exists for them to do better than others with respect to the sale of their commodities. Also, an important point is that a producer who is engaged in the production of more than one crop may prefer stability through pooling for one of the

Table 2. Comparison of United States and Canada Producer Prices, 1955–56 to 1976–77

	Canada				United States		
Year	Initial Payment	Adjustment and/or Interim Payment	Final Payment	Total Producer Price	Total Producer Price Adjusted for Exchange Rate Differences	All Wheat: Season Average Price Received by Producer	Season Average Price Received by Producer Participating in Programs
	($ Canada)				($ U.S.)		
1955–56	1.40	.10	.109	1.609	1.62	1.98	1.98
1956–57	1.40	.10	.088	1.588	1.65	1.97	1.97
1957–58	1.40	.10	.121	1.631	1.68	1.93	1.93
1958–59	1.40	.10	.096	1.596	1.65	1.75	1.75
1959–60	1.40	.10	.090	1.590	1.66	1.76	1.76
1960–61	1.40	.10	.295	1.795	1.79	1.74	1.74
1961–62	1.40	.10	.410	1.910	1.81	1.83	1.83
1962–63	1.50	[a]	.374	1.874	1.74	2.04	2.04
1963–64	1.50		.474	1.974	1.83	1.85	2.03
1964–65	1.50		.387	1.887	1.75	1.37	1.80
1965–66	1.50		.497	1.917	1.78	1.35	1.79
1966–67	1.50		.487	1.987	1.84	1.63	2.22
1967–68	1.70		.114	1.814	1.68	1.39	1.87
1968–69	1.70			1.700	1.58	1.24	1.79
1969–70	1.50	.07	.107	1.680	1.56	1.24	1.89
1970–71	1.50		.171	1.671	1.65	1.33	2.08
1971–72	1.46		.136	1.596	1.60	1.34	1.88
1972–73	1.46	.30	.394	2.154	2.17	1.76	2.23
1973–74	2.25	1.50	.828	4.578	4.64	3.95	4.16
1974–75	2.25	1.50	.720	4.470	4.48	4.09	4.09
1975–76	3.75		.23	3.98	3.95	3.56	3.56
1976–77	3.00		.18	3.18	3.14	2.73	2.73
Average price, 1955–77					2.14	1.99	2.23

Note: U.S. average producer price for all wheat is used in table, and Canadian Wheat Board payments to producers (No. 1 Northern and No. 1 Canadian Western Red Spring).
Sources: Canadian Wheat Board *Annual Report, 1965–66,* Winnipeg, Manitoba, 1967, and selected annual issues; USDA ERS *Food Grain Statistics: Wheat, Rye, Rice, Flour, Byproducts,* supplement for 1971 to Statist. Bull. No. 423, 1972; and USDA ERS CED *Wheat Situation,* WS-192, May, 1965, and selected issues.
[a] Blanks indicate no payment.

crops but not for all of them. Thus, it may be consistent for a producer to support the Wheat Board along with the Winnipeg Grain Exchange where prices for such crops as flax, rye, and rapeseed fluctuate daily.

The producer who chooses to assume marketing risks could use the futures market both as a means of price forecasting and for hedging purposes. In Canada, because of the Board system, there is no active futures market for bread wheats; and what remains at Winnipeg is a rather distorted futures market for feed grains, flaxseed, and the like. However, this does not mean that the Board is isolated from world market influences, as reflected in the futures markets in the United States, nor does it mean that Board actions do not influence world prices as commented upon later.

The distributional effects from futures trading in markets where futures exist have not been clearly demonstrated in the literature. Very recently, some work by Turnovsky, Grossman, and Figlewski has begun looking into this issue. While futures act as a price discovery mechanism (although in the world rice trade, for example, there are no futures and prices are still "discovered") and offer the opportunity to producers to shift unwanted price risks onto those more willing to assume them, there are gainers and losers in futures market activities; those who gain seem to have access to information and capital which others do not have. Thus, it seems that futures trading could benefit large enterprises which may be large farms and/or grain companies, while small farms could suffer serious losses from engaging in these activities.

A related issue involves the role of prices in guiding future resource decisions. In the United States, futures market prices, as well as loan rates and target prices, can be used by farmers in production planning. In Canada, presumably the initial Board payment should be a guide to future production decisions; at

times, there has been a wide gap between the initial and final prices. To the extent that farmers responded to the "low" initial price at the time of planting, producers did not receive a true market price signal on which to base production decisions and, hence, committed to many resources to competing enterprises such as livestock. Again, it is impossible to say a priori which system gives farmers better signals and, therefore, results in better resource use.

Finally, as noted earlier, public policy influences prices in both countries. U.S. decisions with respect to wheat and feed grain programs directly influence producer returns. Similarly, Canadian policy decisions with respect to initial prices, levels of quotas and sales strategies, and freight rates directly influence Canadian producer returns. Given the dominance of the United States and Canada in world grain markets, national policies may also influence world market prices (McCalla; Alaouze, Watson, Sturgess). Decisions relating to stock acquisition and disposal, the level of export subsidies when used in the United States, and the international pricing decisions of the Board clearly influence "world prices" and, therefore, domestic prices and producer returns. Thus, the relative political power of grain growers in the two countries to influence public policy may be as important a factor in relative producer returns as the type of marketing system.

The above discussion of producer prices and returns should be sufficient to show that the difficulties in measuring the relative performance of marketing systems are complicated—it is not simply a matter of comparing prices. It is, however, a fruitful area for further empirical investigation.

Marketing Margins, Market Efficiency, and Information Flows

Unlike producers in the United States, the Canadian producers know the average prices of grain sold by the Board and, hence, the marketing margins. Margins are known because the costs of marketing grain, including salaries of Wheat Board personnel, are published. Data on marketing costs and returns to shareholders of the large, private, multinational grain companies are not made public. Therefore, it is extremely difficult to obtain evidence on the performance aspects of the private grain trade in the United States.

A point often overlooked in grain-marketing analysis is the interface between governments and the major marketing institutions. Governments design trade policies and, for these to be effectively implemented, a monitoring system is needed to provide key information such as how much of the good is available for export. One strong feature of the Canadian system is that it is easy for the government to assess the supplies of various grains available for export because the Board, due to its role as a sole seller of grain on the international market, has the necessary information. This type of central information source generally has not been available in the United States, as evidenced, for example, by the 1973–76 period when confusion existed over the magnitude of grain sales that were being made by the private companies. In addition, due to the nature of the Board system which requires that all sales be made through the Board, it is impossible in Canada for foreign buyers—many of whom are government agencies—to deal secretively and at times simultaneously with different exporting companies. This is not the case in the United States. Through this process, the Board has been able to sign long-term agreements with importers; whereas, in the United States, there has been a reluctance to do so largely because the basis for carrying out trade is with the private exporting companies—a factor which adds to the instability of the world grain market.

Concerning the flow of information, although the U.S. government recently passed legislation that requires the private grain companies to report sales above a certain magnitude, it is not clear that such a requirement can be enforced properly because of the multinational nature of the grain-exporting companies. For example, it seems possible that a subsidiary located outside the United States could make a forward sale and transmit it as an intracompany communication to a parent company located in the United States, thus permitting the parent company to begin to acquire the grain prior to the U.S. report of an actual transaction. In addition, it is probable that it could report to the home company in piecemeal fashion in amounts less than the minimum reporting requirement. In either case the effect of the reporting requirement would be to report on a purchase and sale after the effective date of the original transaction. In such cases producer prices could be kept arbitrarily low during the time purchases are made by the grain companies.

In addition, the large private companies buy not only from U.S. producers; they often buy wheat outright from the Board and at other times act as agents for the Board when the private trade does the shipping and the like. Thus, it is not clear as to whether or not the welfare of producers in the United States relative to other world producers is maximized. In theory, at least, multinationals have a whole host of sources of supply which they could match into the numerous world import demands, and thus it makes little difference to the multinationals where the source of supply originates.

Physical Efficiency and Progressiveness

Data are scarce which would allow the determination of the extent to which grain-marketing technology has been introduced in both countries. However, it does appear that hopper boxcars and unit trains, for example, first were developed and used in the United States and have only recently surfaced in Canada. (It appears that, due to these and such factors as marketing margin adjustments, the United States marketing system can adjust more rapidly to erratic change in supply and demand conditions such as those in the early 1970s.) One could argue that until recently there was relatively little improvement in the Canadian grain-marketing technology, which may partly explain why the U.S. market share in the world wheat trade has increased *vis-à-vis* Canada's share.

However, in assessing the issue of differences among countries with respect to grain-handling technology, climatic differences can have a significant impact. For example, the unit trains were first introduced in the United States in areas which had large outputs per acre. These areas generally produced hybrid corn which greatly outyields nonirrigated wheat in Canada.

Export Performance

Table 3 presents data on export market shares of Canada and the United States for the period, 1965–78. The data suggest that, in the period 1966–70, both U.S. and Canadian shares fell. In the period 1971–76, the Canadian share fell while the U.S. share increased significantly. In the last two years, the Canadian share rose while the U.S. share fell.

Equity Issues

The very nature of the quota system and pool prices in Canada is designed to equalize access of individual farmers to the market. It is clear that this has been accomplished. The system is based both on efficiency and equity criteria. There is no a priori conclusion which can be reached about the undesirability of a system which incorporates both aspects. To the extent that individual producers are risk averters and lack sufficient information to take effective advantage of market changes, the system has contributed to equity in the distribution of

Table 3. Total Wheat Exports of the World, Canada, and the United States, 1965–78

Crop Year	World	Canada	Canadian Exports as a percentage of World Total	United States	U.S. Exports as a percentage of World Total
	– million metric tons –			million metric tons	
			%		%
1965–66	61.1	14.9	24.4	23.4	38.3
1966–67	57.3	14.8	25.8	20.0	34.9
1967–68	53.1	8.9	16.8	20.2	38.0
1968–69	50.0	8.7	17.4	14.7	29.4
1969–70	55.3	9.0	16.2	16.5	29.8
1970–71	56.3	12.6	22.4	19.8	35.2
1971–72	57.7	15.8	27.4	16.9	29.3
1972–73	72.8	15.6	21.4	31.8	43.7
1973–74	69.1	11.5	16.6	31.1	45.0
1974–75	68.8	11.2	16.3	28.0	40.7
1975–76	72.8	12.1	16.6	31.5	43.3
1976–77	68.5[a]	12.9[a]	18.8	25.7[a]	37.5
1977–78	76.4[b]	16.0[b]	20.9	29.7[b]	38.9

Source: USDA ERS CED, *Wheat Situation*, WS-232, May 1975, p. 40, and selected issues.
[a] Preliminary.
[b] Projected.

marketing opportunities. However, by the very nature of the system, the pooling and quota policies prevent individual producers from adjusting their marketing to take advantage of rising and changing market conditions throughout a given year. Thus, superior managers cannot *vis-à-vis* their inefficient counterparts, take advantage of their marketing skills. Also, over the longer term, the quota system has generally favored farmers who, for whatever reasons, do not completely specialize in grains and those on land which is marginal for wheat production.

Because of the pooled pricing arrangement in Canada, the payoff for having highly refined short-term price forecasting techniques is not as great as it is in the United States. In the latter, the wheat farmer has to do a good job in both production and marketing to have a profitable enterprise.

Conclusions

There has been considerable discussion as to whether or not the Canadian grain-marketing system is better than that of the United States. The purpose of this paper is to set the stage for further research on this topic rather than to provide definitive answers. As this paper points out, assessing the performance of the two systems is a very complex task.

In the United States, public sector, direct involvement in the marketing task has been limited. The physical task of marketing—primary delivery, transportation, storage, and transformation—is almost completely in private hands with few public policies pertaining. Until 1976, grading (with federal supervision) was in private hands. The institutions that provide services to the marketing system are exclusively private as are the price formation mechanisms. The major public interface with the grain-marketing system has been indirect via the pervasive influence that federal price- and income-support programs have had on the volume, mix, and producer prices of grain products.

In contrast, public involvement permeates the marketing system in Canada. Public institutions are directly involved in setting rates for storage and transportation, managing deliveries to the elevator system, owning storage facilities, grading grain, setting prices, and conducting the export trade. Thus, the entire marketing system in Canada has been historically, and continues to be, a mix of public and private actors with the public sector directly involved as a participant in many marketing functions. However, the influence of Canadian public policy on grain production and, therefore, indirectly on this marketing system is significantly less than in the United States. Thus, the two marketing systems are very different. In Canada public elements exist as integral parts of the marketing system but tend to have limited indirect effects. In the United States, direct, public sector involvement in marketing functions has been limited, but the indirect influence of U.S. price and income policy has been substantial. Given current knowledge, it is not known whether or not more or less government involvement would improve the marketing system in either country. It is important to stress that, although the Board is supported by most growers and agricultural groups in Canada, it does not mean that it is necessarily a model that has transferability. The character of the Board is a unique function of Canadian history and institutions and, as such, it should be judged only in that context.

[*Received September 1978; revision accepted January 1979.*]

References

Alaouze, Chris M., A. S. Watson, and N. H. Sturgess. "Oligopoly Pricing in the World Wheat Market." *Amer. J. Agr. Econ.* 60(1978):173–85.

Bain, Joe S. *Industrial Organization.* New York: John Wiley & Sons, 1959.

Brandow, G. E. "Appraising the Economic Performance of the Food Industry." *Lectures in Agricultural Economics.* USDA ERS Bicentennial Year Lectures, June 1977, pp. 81–100.

Bressler, Raymond G., and Richard A. King. *Markets, Prices and Interregional Trade.* New York: John Wiley & Sons, 1970.

Canadian International Grains Institute. *Grains and Oilseeds: Handling, Marketing, Processing.* Winnipeg, Canada, May 1975.

Canadian Pacific Rail. *Farmer's Net Return/Bushel: A Canada-U.S.A. (Northern States) Comparison.* Montreal, Canada, 1977.

Canadian Wheat Board. *About the Canadian Wheat Board.* Winnipeg, Canada, no date.

Caves, Richard E. "Organization, Scale, and Performance in the Grain Trading Industry." Harvard Institute of Economic Research. Disc. Pap. 546, 1977.

Cochrane, Willard W., and Mary E. Ryan. *American Farm Policy, 1948–1973.* Minneapolis: University of Minnesota Press, 1976.

Currie, J. M., J. A. Murphy, and A. Schmitz. "The Concept of Economic Surplus and Its Use in Economic Analysis." *Econ. J.* 81(1971):741–99.

Davis, J. S. *Wheat and the AAA*. Washington, D.C.: The Brookings Institution, 1935.

Figlewski, S. "Market Efficiency in a Market with Heterogeneous Information." *J. Polit. Econ.* 86(1978):581–97.

Frevalds, John. *Grain Trade: The Key to World Power and Human Survival*. New York: Stein and Day, 1976.

Goldberg, Ray A. *Agribusiness Coordination: A Systems Approach to the Wheat, Soybeans and Florida Orange Economies*. Div. of Res., Graduate School of Business Administration, Harvard University, 1968.

Grossman, S. J. "The Existence of Futures Markets, Noisy Rational Expectations, and Informational Externalities." *Rev. Econ. Stud.* 44(1977):431–49.

Hill, Lowell D., and P. J. Van Blokland. "Grain Marketing." *Advances in Cereal Science and Technology*, ed. Y. Pomeranz, pp. 1–40. St. Paul, Minn.: American Association of Cereal Chemists, 1976.

Jesse, E. V. "Measuring Market Performance: Quantifying the Non-Quantifiable?" North Central Project 117, Work. Pap. 15, March 1978.

Kulshreshtha, S. N., and D. G. Devine. "Historical Perspectives and Propositions on the Crowsnest Pass Freight Rate Agreement." *Can. J. Agr. Econ.* 26(1978):72–83.

Mann, J. S. "Techniques to Measure Social Benefits and Cost in Agriculture: A Survey." *Agr. Econ. Res.* 29(1977):115–26.

McCalla, A. F. "A Duopoly Model of World Wheat Pricing." *J. Farm Econ.* 48(1966):711–27.

Rasmussen, W. D., and G. L. Baker. "A Short History of Price Support and Adjustment Legislation and Programs for Agriculture, 1933–65." *Agr. Econ. Res.* 18(1966):69–78.

Schmitz, A., and A. F. McCalla. "Comparison of Canadian and U.S. Grain Marketing Systems." Washington, D.C.: National Grain and Feed Association, Mar. 1976.

———. "The Canadian Wheat Board." *Agricultural Marketing Boards: An International Perspective*, ed. S. Hoos, in press.

Treleavan, D. H. *Speech to Fifth International Grains Industry Course*. Winnipeg, Can.: Canadian International Grains Institute, 10 Sept. 1975.

Turnovsky, S. J. "Futures Markets, Private Storage, and Price Stabilization." Mimeographed. Canberra: Australian National University, 1978.

U.S. Congress, Senate, Committee on Agriculture and Forestry. *Report on Irregularities in the Marketing of Grain*. 94th Congress, 2d session, Joint Committee Print, 17 Feb. 1976.

U.S. Department of Agriculture (USDA). *Agricultural Statistics*, various issues.

The Effects of Federal Milk Orders on the Economic Performance of U.S. Milk Markets

W. D. Dobson and Larry E. Salathe

Class I price differentials maintained by the U.S. Department of Agriculture and producers during 1965–75 generated Grade A milk supplies in excess of fluid needs and reserves for the federal order system. As required by specified norms, USDA has adopted federal milk order provisions which reduce pronounced seasonality of milk production and lessen certain types of erratic and extreme price variation. If federal milk orders were eliminated and cooperatives and state agencies were barred from replacing the orders, then fluid milk markets characterized by lower Class I differentials, greater milk price variability, and smaller Grade A milk surpluses might emerge.

Key words: economic deregulation, federal milk orders, price discrimination.

When Senator Edward Kennedy spoke at a 1975 conference on milk prices and the market system, he remarked that "milk marketing regulation has . . . gone astray. (Moreover), the need to lighten the burden imposed by unnecessary federal regulation challenges all of us—consumers, scholars, producers, regulatory agencies and legislators—to rethink and revise our federal milk marketing system" (p. 13). Some rethinking of the type called for in the Senator's remark has occurred.

In their study of benefits and costs associated with federal and state regulation of milk markets, Ippolito and Masson concede that milk orders increase the incomes of Grade A milk producers who sell milk under the orders, but point out that the devices also reduce the incomes of manufacturing milk producers and fluid milk consumers. It is not clear, they suggest, that such transfers of income can be legitimately claimed as a social benefit. Moreover, they claim that most of the other classic alleged benefits of regulation (e.g., price stability and orderly marketing) are of questionable validity, particularly in the context of present market conditions.

Buxton cites evidence which suggests that the differential between Class I and manufacturing milk prices in federal order milk markets has been too large (p. 526). Eisenstat, Masson, and Roddy charge that some cooperatives operating in federal order markets have employed predatory competitive practices to obtain Class I premium prices (p. 539). The National Consumers' Congress contends that certain Class I premiums negotiated by milk cooperatives constitute undue price enhancement in violation of the Capper-Volstead Act (Capper-Volstead Committee).

Producer groups and others dispute charges that benefits now produced by the orders are of questionable validity and that Class I differentials are too large. They also argue that Class I premiums are essential to compensate cooperatives for providing needed market-level services in federal order markets.

This article (*a*) provides additional analysis of the effects of federal milk orders on the economic performance of U.S. milk markets, and (*b*) examines what U.S. milk markets might be like in the absence of federal milk orders. The performance evaluation focuses mainly on examining pricing policies pursued by USDA and milk cooperatives and on how federal milk orders have affected price and market stability in recent years.

W. D. Dobson is professor and chairman of agricultural economics at the University of Wisconsin, Madison. Larry E. Salathe was employed as a research associate in the Department of Agricultural Economics at the University of Wisconsin-Madison, when this study was conducted.

Financial support for the research was provided by the Wisconsin Agricultural Experiment Station.

Helpful comments on the manuscript by Robert Masson, Ron Knutson, and the anonymous reviewers are gratefully acknowledged.

Evaluation of Federal Milk Order Pricing Policies

Harris indicates that classified pricing can be employed to pursue the stability objective or the price enhancement objective. If the stability objective is pursued, then, according to Harris, classified pricing is used mainly to eliminate the destabilizing effects of "flat pricing."[1] Under this objective, little effort is made to obtain, except seasonally, higher returns for producers through exploitation of the relatively inelastic fluid milk demand.[2] Consequently under the stability objective, there is little or no tendency for fluid milk consumption to fall or for fluid (Grade A) milk surpluses to expand (*ceteris paribus*). When the price enhancement objective is pursued, classified pricing is employed to raise producer prices to levels substantially higher than would be warranted if milk were sold for a single price. Under this objective, there is a tendency for fluid milk consumption to fall and blend prices to increase at first in response to increases in Class I prices and then decline as total market supplies and the proportion of surplus Grade A milk increases. When pursuit of the price enhancement objective generates Grade A milk surpluses, costs associated with producing more Grade A milk than needed for fluid markets may be incurred and returns to manufacturing (Grade B) milk producers may decline.

Under the Agricultural Marketing Agreement Act of 1937, the Secretary of Agriculture is required to establish milk prices which "insure a sufficient quantity of pure and wholesome milk, and (will) be in the public interest" (U.S. Department of Agriculture 1971, p. 19). This "supply-demand" criterion has been interpreted as requiring USDA to establish milk prices which elicit an adequate but not excessive supply of fluid grade (drinking) milk for federal order markets. The criterion also suggests that USDA should employ pricing policies that produce results similar to those associated with Harris' stability objective.

Class I prices in federal order markets presently consist of two components, the Class I differential and the Minnesota-Wisconsin manufacturing milk (basic formula) price lagged two months. Class I differentials represent policy variables which USDA can manipulate to influence Grade A milk supply levels in federal order markets. Producers also can increase the effective Class I differentials by negotiating Class I premiums. Thus, if USDA or producers wished to achieve performance of the type associated with the stability objective, then they would reduce (increase) Class I differentials when supplies of Grade A milk exceeded (fell short of) Class I sales plus required reserves in the markets (Norm No. 1). They also would establish Class I differentials which induced only those producers whose milk is required for fluid needs to convert from Grade B to Grade A milk production (Norm No. 2). A related requirement is that the highest manufacturing class prices consistent with continuous disposal of surplus milk be maintained in the markets (Norm No. 3). How do USDA's pricing policies and those of the cooperatives fare when evaluated against these norms?

Changes in Federal Order Minimum Class I Differentials

Average Class I differentials for all federal order markets and for the Chicago market appear in table 1. These differentials were computed by subtracting from monthly federal order minimum Class I prices the Minnesota-Wisconsin manufacturing milk price for either the preceding month (for January 1965–January 1972) or the second preceding month (for February 1972–December 1975). Class I differentials computed by this procedure represent a simplification of the actual situation, since, early in the 1965–75 period, federal order markets in the northeastern United States employed economic formula prices. In markets with economic formula prices, Class I differentials which are completely comparable to those computed by the above procedure did not exist. Moreover, the annual average Class I differentials in table 1 obscure some intrayear variation in the differentials which resulted from "supply-demand" adjustments and seasonal adjustments.

USDA increased the average minimum

[1] Under "flat pricing," producers sometimes are cut off from markets when milk supplies increase seasonally. When classified pricing is employed, seasonal surpluses of milk in excess of fluid needs cost the processor only the manufacturing milk price. Therefore, classified pricing reduces the processor's incentives to cut off producers from the plant in the spring when milk supplies increase seasonally.

[2] However, Class I prices which exceed, by some variable amount, the manufacturing milk price are expected under the stability objective. Some price differential is needed to compensate producers for the added cost of producing Grade A milk rather than Grade B milk and to attract needed fluid milk supplies to the market especially during the seasons of highest fluid milk demand.

Table 1. Changes in Minimum Class I Differentials in Federal Order Markets, 1965–75

Year	Average Class I Differential for all Federal Orders ($)	Percentage of 1965 Class I Differential	Average Class I Differential for Chicago Federal Order ($)	Percentage of 1965 Class I Differential
1965	1.72	100.0	.76	100.0
1966	1.76	102.3	.74[a]	97.4
1967	1.92	111.6	N.A.[b]	N.A.[b]
1968	2.08	120.9	1.31[c]	172.4
1969	2.11	122.7	1.22	160.5
1970	2.08	120.9	1.22	160.5
1971	2.10	122.1	1.26	165.8
1972	2.10	122.1	1.26	165.8
1973	2.09	121.5	1.26	165.8
1974	2.10	122.1	1.26	165.8
1975	2.09	121.5	1.26	165.8

Note: Prices employed for computing the Class I differentials were obtained from USDA, *FMO Statistics*, 1965–75.
[a] Average for January–April 1966.
[b] There was no Chicago order in effect during May 1966–June 1968.
[c] Average for July–December 1968.

Class I differential for all federal orders by $.36 during 1965–68 when milk supplies in the markets tightened temporarily (table 1). The USDA then held the differentials nearly constant at about $2.10 from 1968–75. The Class I differential for the large Chicago market was increased by about $.50 per hundredweight in the late 1960s and early 1970s to the present $1.26 level.

It appears that the larger Class I differential which USDA established for Chicago increased blend prices in the Chicago milkshed to the point where additional Grade B milk producers converted to Grade A production even though their milk was not required for the fluid market. Frank, Peterson, and Hughes estimated that the additional cost of producing Grade A milk rather than Grade B milk near Eau Claire, Wisconsin (a city near the outer edge of the Chicago milkshed) averaged $.27 per hundredweight in 1974.[3] According to these researchers, costs were higher for producing Grade A milk because of higher capital investment costs and additional labor costs (i.e., higher labor costs for extra cleaning of milk utensils, milkhouses, and barns to meet the more stringent Grade A sanitary requirements) on the Grade A dairy farms.

Grade A milk supplies pooled under the Chicago federal order in 1974 appeared to be more than adequate since only 39% of the milk for the market was being used in Class I. When fluid utilization for the Chicago market is 39%, a $.70 Class I differential is needed to return the Grade A milk producer located near Eau Claire a blend price $.27 higher than the manufacturing milk price. In the longer run, a lower Class I differential might reverse the trend to Grade A milk production in the market and increase the proportion of fluid eligible milk used for fluid purposes. Factors such as lack of markets for Grade B milk might limit the increase in Grade B milk production and restrict the increase in fluid utilization arising from a lower Class I differential. However, as suggested later, it may be feasible for fluid utilization in federal order markets to increase to a level where the total Grade A milk reserve equals only a seasonal reserve and an additional reserve equal to 25% of Class I sales. If, despite a long history of large reserves, Class I utilization in the Chicago federal order market rose to the 73% level associated with such a smaller Grade A milk reserve, then a Class I differential of $.37 would return to the milk producer at Eau Claire a blend price covering the added cost of producing Grade A milk. The $.70 and $.37 figures therefore bracket the size of the Class I differential required to return the Eau Claire producers a blend price that covers the added cost of producing Grade A milk. The present Chicago Class I differential adjusted to the Eau Claire location is $.90

[3] Their results differ from those of Cummins, who found no statistically significant difference between 1974 production costs on Grade A and Grade B dairy farms in the upper Midwest. A dairy farmer who is equipped to produce either Grade A or Grade B milk almost invariably will incur at least the additional labor costs required for meeting more stringent Grade A sanitary requirements if he opts to produce Grade A milk. Accordingly, our analysis is based on the cost figures reported by Frank, Peterson, and Hughes, which show higher costs for producing Grade A milk.

per hundredweight. Thus, USDA's actions regarding the Class I Chicago differential apparently fail to measure up to those called for in Norm No. 2.

Judgments about whether USDA adjusted the average Class I differential for all federal orders during 1965–75 in ways called for in Norm No. 1 are deferred until after data on Class I premiums and Grade A milk surpluses for the federal order system are discussed.

Changes in Negotiated Class I Premiums

The National Consumers' Congress charged that premiums negotiated by cooperatives in 1974–75 constituted undue price enhancement in violation of Section 2 of the Capper-Volstead Act. The Capper-Volstead Committee rejected this allegation, arguing that Class I premiums represent mainly compensation to producers for marketing services rendered and that the higher Class I premiums observed in 1974–75 were justified by unusual economic conditions confronting producers. Can the Class I premiums observed in recent years be explained as compensation to producers for marketing services and an "appropriate" response to economic adversity? Have Class I premiums increased effective Class I differentials to the point that performance associated with the price enhancement objective is produced?

To examine these questions, a sequence of weighted average Class I premiums was constructed for 1965–75 for seventeen city milk markets representing a cross-section of federal milk orders.[4] The Class I premiums for 1965 to mid-1973 averaged \$.18 per hundredweight in the seventeen markets. Beginning in mid-1973, the cooperatives negotiated larger premiums for the seventeen cities which averaged \$.40, \$.55, and \$.52 per hundredweight for the last half of 1973 and the years 1974 and 1975, respectively. The Class I premiums for the seventeen cities during 1974 and 1975 were moderately smaller than those reported for a larger thirty-one market group for which USDA issued Class I premium figures beginning in the mid-1970s. In the latter group of markets Class I premiums averaged \$.66 and \$.62 during 1974 and 1975, respectively (USDA, *Class I Premiums*, July 1973–December 1975).

Producer cooperatives incur costs for providing market-level services (e.g., handling surplus milk, full-supply arrangements, dairy product advertising) which benefit both handlers and producers and farm-level services (e.g., checking producer milk weights and butterfat tests, field services, negotiating farm-to-plant hauling rates) which benefit mainly producers. Deiter, Gruebele, and Babb developed estimates of costs incurred by thirty-one dairy cooperatives in the North Central Region for providing market-level and farm-level services in 1973. They found that costs incurred by smaller cooperatives for providing market-level services averaged \$.03 per hundredweight, while those sustained by the largest cooperatives (which provided more of these services) averaged \$.10 per hundredweight. The Capper-Volstead Committee reports that when over-order payments on Class I milk have been \$.30 per hundredweight or less, producer pay prices of the largest cooperatives operating in the federal order markets generally have been at the order blend price or below (p. 32). Therefore, if one deducts an estimate of the full cost of farm-level services (which, according to Deiter, Gruebele, and Babb, averaged about \$.05 per hundredweight) from the \$.30 figure, then a \$.25 per hundredweight estimate is obtained for the cost of providing market-level services. The Deiter, Gruebele, and Babb and Capper-Volstead Committee estimates, therefore, bracket the costs of providing market-level services within a range of about \$.03 to \$.25 per hundredweight. Hence, the \$.18 average Class I premium that prevailed in the seventeen cities during 1965 to mid-1973 might be identified mainly as representing compensation to cooperatives for rendering market-level services.

In some markets, the Class I premiums for 1965 to mid-1973 exceeded the seventeen market average and persistently exceeded the higher of the figures (\$.25 per hundredweight) reported above for the cost of market-level services. For example, in Chicago, Dallas, Minneapolis, and Detroit (southern Michigan) the Class I premiums exceeded \$.25 per hundredweight for more than twenty-four months in succession during some part of the 1965 to

[4] The 17-city price series consisted of Class I premiums for Atlanta, Boston, Chicago, Milwaukee, Cincinnati, Cleveland, Pittsburgh, Dallas, Detroit, Kansas City, Minneapolis, New York, Baltimore, Philadelphia, Washington, D.C., St. Louis, and Seattle. (Source of figures: USDA, *FMC Rep.*, January 1965–June 1973 and USDA, *Class I Premiums*, July 1973–December 1975.) The markets represented in the series accounted for 60% of the Class I sales in the federal order system in 1975. The sequence of premium prices was computed by weighting Class I premiums for the 17 city markets by Class I sales in these markets.

mid-1973 period. These figures raise questions about whether cooperatives in these four markets exercised market power to secure premiums which persistently exceeded the cost of providing market-level services. Questions concerning market power also can be raised regarding the larger average Class I premiums that emerged in the seventeen cities during mid-1973 through 1975.

What conditions precipitated the apparent exercise of market power by cooperatives to secure larger premiums during the latter period? Federal order minimum Class I prices fell 14%, from $10.05 during the first half of 1974 to $8.65 during the last half of the year, and remained under $10.00 until November 1975. During this period when federal order minimum Class I prices were below $10.00, prices dairy farmers paid for inputs were rising (Capper-Volstead Committee, p. 22). For example, from mid-1974 to mid-1975 prices of U.S. farm production items increased by 15%. Livestock feed prices were volatile during this period and exhibited some sharp increases. For example, from mid-July 1974 to mid-October 1974 livestock feed prices for the United States rose 18%. According to the Capper-Volstead Committee, USDA denied requests from producers for increases in federal order minimum Class I prices in the fall of 1974, telling them to "negotiate such increases as they could in the marketplace" (p. 34). Therefore, if cooperatives had failed to negotiate the larger Class I premiums in 1974–75, milk producers would have experienced a cost-price squeeze. The cost-price squeeze could have had varying effects, ranging perhaps from increasing farmer debts to forcing some beginning and marginal farmers out of business.

The Agricultural Marketing Agreement Act of 1937 specifies that federal milk orders shall set only the minimum (not the exact or ceiling prices) which regulated handlers must pay for milk. It has been argued that this provision was included in the Act partly to permit rapid price increases (outside the pricing mechanism of the orders) when adverse economic prospects faced milk producers (Capper-Volstead Committee, pp. 4–7). If one accepts this argument, then it appears that cooperatives were justified in negotiating larger Class I premiums during 1974–75. It is noteworthy, too, that average Class I premiums in thirty-one markets declined to $.34 per hundredweight in 1976 after the recovery of federal order minimum Class I prices (USDA, *Class I Premiums* 1976).

The conclusion reported above for 1974–75 should not be interpreted to mean that all the larger Class I premiums in the federal order markets during these two years were necessarily justified by economic conditions. Moreover, the analysis did not investigate whether some cooperatives obtained larger Class I premiums by using predatory practices. The predatory practice matter involved legal questions which are beyond the scope of this study.

It was estimated that during 1965 to mid-1973 the $.18 average Class I premium for the seventeen markets would have increased consumer milk prices by .75¢ per half gallon, reduced fluid milk consumption by .5%, and increased milk supplies by 1% or less.[5] These Class I premiums therefore contributed relatively little to producing performance of the type associated with the price enhancement objective. This appears to be less true of the larger Class I premiums which emerged during mid-1973 through 1975. The negotiated premiums for the latter period would have raised consumer prices by about $.02 per half gallon and reduced fluid consumption by about 1% in the seventeen city markets. If the larger Class I premiums of mid-1973 through 1975 kept additional producers in business, then they may contribute to higher milk production in federal order markets for an extended period into the future.

Problems may arise if large Class I premiums persist for an extended time. In southern Michigan, for example, Class I premiums averaged about $.37 per hundredweight higher than the average premiums for the seventeen city group during 1965–75. The southern Michigan premiums presumably contributed to the 20% Grade A milk surplus (discussed later) which existed in that market in 1975.

Nourse et al. remarked as follows about such premiums in 1962: "When free collective

[5] The estimates of the impact of the Class I premiums on consumer milk prices and fluid milk consumption were made using a −.35 retail price elasticity of demand estimate (average of elasticities reported by Burk, George and King, Wilson and Thompson, and Rojko) and average retail milk prices for 1965 to mid-1973 ($.55 per half gallon) and mid-1973 through 1975 ($.75 per half gallon) for the 17 cities. The results reflect the assumption that the premiums were passed along to consumers in the form of higher prices on a dollar-for-dollar basis. The effects of the negotiated premiums on milk supplies during 1965 to mid-1973 were computed using blend prices and Class I utilization figures for the 17 markets and the average of the .15 to .52 long-run supply elasticity estimates reported by Wipf and Houck, Wilson and Thompson, and Halvorson.

bargaining by strong cooperative associations results in negotiated marketwide premiums substantially and persistently above the uniform price established in the order, an ambiguous and dangerous situation confronts the order system. Either the Class I price in the order is too low or the premium price is too high by an 'open market' standard" (pp. 98–99). Nourse et al. recommended that "in markets where . . . premiums . . . exist the Department (should) institute hearings to review the level of Class I prices and any limitation on free access to the market. If, thereafter, such premiums still persist consideration should be given to suspension of the pricing and pooling provisions of the orders" (p. 99).

Belated adoption of the Nourse et al. recommendations should be helpful for dealing with what appears to be a neglected problem. If facts gathered at the hearings show that Class I premiums in a market have remained consistently higher than necessary to cover costs incurred by producers for providing needed market-level services and create blend prices which generate more than adequate supplies of Grade A milk, then USDA might engage in "jawboning" and other types of persuasion to reduce the premiums. Presumably, more drastic measures such as the suspension of the orders would be needed only if persuasion repeatedly failed to produce desired results.

Changes in Grade A Milk Surpluses in Federal Order Markets

Figures showing the estimated percentages of Grade A milk in excess of fluid needs plus required reserves (surplus Grade A milk) pooled under the ten largest federal orders and the federal order system during 1955–75 appear in table 2. The percentages in table 2, which help to identify whether USDA pursued pricing policies called for in Norm No. 1, were computed from daily average figures for producer milk receipts and producer milk used in Class I using the following formula: percentage of Grade A milk in excess of fluid needs plus required reserves equals [(producer receipts − 1.25 × producer milk used in Class I − seasonal reserve)/producer receipts] × 100.

This formula assumes that each federal order market requires a seasonal reserve and an additional reserve equal to 25% of Class I sales. The formula's seasonal reserve component equals the average daily milk production for the year minus average daily production during the month of low production for the year.

Cook, Blakley, and Berry (p. 11) estimate that a Grade A milk reserve equal to at least 20% of Class I sales is required for a federal order market. Rosenbury (p. 9) estimates that a reserve equal to 26% of Class I sales is the minimum workable reserve for a federal order market. In order to compare the Grade A milk surplus estimates computed with the formula (which are expressed as a percentage of producer receipts) to those reported by the other authors, the Grade A milk surplus figures for the "All Federal Order Markets" row in table 2 were expressed as a percentage of Class I sales. This revealed that the formula produced estimates of total necessary seasonal plus additional reserves which averaged 37% of producer milk used in Class I for 1955, 1960, 1965,

Table 2. Estimates of Grade A Surplus Milk in Ten Largest Federal Order Milk Markets and Federal Order System, Computed Using a 25% Class I Sales Reserve and a Seasonal Reserve

	Percentage of Grade A Surplus Milk				
Market	1955	1960	1965	1970	1975
New York-New Jersey	26.7	24.4	26.1	22.3	30.7
Chicago regional	19.8	28.8	26.9	35.5	46.4
Middle Atlantic	−0.3	3.4	−6.7	14.9	15.8
Southern Michigan	2.2	7.9	19.6	15.3	19.6
Texas	−12.9	0.6	5.2	−3.0	1.5
Boston regional	12.2	13.5	13.5	16.3	20.5
Eastern Ohio-Western Pennsylvania	3.3	5.3	5.6	6.5	13.3
Ohio Valley	5.3	10.9	4.6	5.2	13.5
Minneapolis-St. Paul[a]	−1.7	3.8	2.5	31.5	40.4
St. Louis-Ozarks	−16.5	−5.5	−2.1	6.8	7.8
All federal order markets	13.2	12.8	13.4	16.9	20.4

Note: Figures employed to compute the estimates of milk surpluses were obtained from USDA, *FMO Statistics*, 1955–75.
[a] Presently included in upper Midwest federal milk order.

1970, and 1975. Therefore, the estimates of required reserves computed with the formula are higher than the minimum reserve figures reported by the other authors. However, it was considered appropriate to employ the formula since we desired to minimize the probability of erroneously labeling some portion of needed reserves as Grade A milk surpluses.

Admittedly, alternative procedures might have been employed to compute estimates of the Grade A milk surpluses. A plausible alternative procedure would involve measuring on a market-by-market basis the required Grade A milk reserves rather than employing a formula which seeks to minimize the probability of identifying needed reserves as Grade A milk surpluses. Such an alternative procedure would likely produce estimates of Grade A milk surpluses for the federal order markets which are larger than those reported in table 2. Therefore, it is not clear that the implications to be obtained from use of this alternative procedure would differ substantially from those reported in the present inquiry.

Grade A milk surpluses in the federal order system increased from 13% of producer receipts in 1955 to 20% of producer receipts in 1975 (table 2). The 20% surplus figure for 1975 is equal to about 12% of all milk produced in the United States and 23% of all milk used for manufacturing purposes in the country in 1975.[6]

The growth of Grade A milk surpluses in the federal order markets is what one might expect if USDA were pursuing the price enhancement objective. Of course, not all the Grade A surplus can be attributed to USDA's policy regarding Class I differentials. As suggested earlier, large, persistent, Class I premiums might have contributed to the surpluses in some markets. However, the impact of the Class I premiums should not be overestimated since in many markets these premiums were small until mid-1973, and there was a buildup of Grade A milk surpluses underway before that date. Second, in the upper Midwest, factors in addition to USDA's decision to increase the Chicago Class I differential may have induced producers to convert from Grade B to Grade A milk production and pool their milk under federal orders. For example, in Wisconsin, operators of dual-intake plants who wished to reduce costs by handling only one grade of milk sometimes required producers who wished to sell milk to them to convert to Grade A and pool under a federal order.

Nonetheless, if USDA wished to achieve results called for in Norm No. 1, then Class I differentials should have been lowered in recent years. Administrators of the federal milk order program (USDA officials) who were contacted during the study raised questions about drawing such an inference, arguing that (*a*) no prescription for reducing Class I differentials emerges if USDA dairy product price support purchases—especially those for the mid-1970s—are considered in defining surpluses in federal order markets, (*b*) the milk defined in table 2 as surplus Grade A milk is mainly milk supplied by former Grade B milk producers who have converted to Grade A milk and pool their milk under federal orders, (*c*) it is inevitable that sometime soon all milk in the United States will be Grade A, and (*d*) the limited changes in Class I differentials which might be feasible would not reverse the trend toward production of Grade A milk and pooling of this milk under the orders.

Purchases of manufactured milk products under the dairy price support program averaged 4.3 billion pounds of milk equivalent (3.5% of United States milk production) during 1955, 1960, 1965, 1970, and 1975 (Dobson and Buxton, p. 11). The price support purchases for these five years ranged from a high of 5.8 billion pounds of milk equivalent in 1970 (4.9% of United States milk production) to a low of 2.0 billion pounds of milk equivalent in 1975 (1.8% of United States milk production). Milk surpluses for the United States in 1975, as measured by USDA price support purchases, were smaller than the 1975 Grade A milk surpluses reported in table 2 for all federal order markets. There is no contradiction in the two measures of milk surpluses for 1975. They simply show that a surplus of Grade A milk may exist when overall supplies of milk for the United States are relatively tight. When situations of the type that prevailed in 1975 are encountered, it appears appropriate to ask: What is in short supply; Grade A milk in federal order markets, or all milk (Grade A plus Grade B milk) in the United States? Thus, if there is a need to increase (decrease) supplies of Grade A milk in the federal order

[6] When an additional reserve equal to 20% (rather than 25%) of Class I sales was employed with the seasonal reserve, the estimated amount of Grade A surplus milk in the federal order system for 1975 increased to 23% of producer receipts. The 23% surplus figure equals about 14% of all milk produced in the United States and 26% of all milk used for manufacturing purposes in the country in 1975.

markets, then increases (decreases) in the Class I differentials are called for, as suggested by Norm No. 1. If, on the other hand, there is enough Grade A milk for fluid needs and required reserves in federal order markets but there is concern that the overall milk supply for the United States will be inadequate, then an increase in the dairy price support may be called for so that both Grade A and Grade B milk producers share in the higher prices. Therefore, given the size of the Grade A milk surpluses in federal order markets in 1975, it does not appear that a prescription calling for lower Class I differentials is invalidated by the 1975 data on USDA dairy price support purchases.

Conversion of producers in the upper Midwest (especially those in the Chicago and Minneapolis-St. Paul markets) from Grade B to Grade A milk production doubtless produced a sizable amount of the aggregate Grade A surplus milk. However, in some large markets in the Northeast (e.g., the New York-New Jersey and Boston regional markets) Grade A milk surpluses increased during 1965–75 (table 2), although all but about 2% of the milk produced in many northeastern states which supply these markets has been Grade A since the late 1950s (USDA 1967, p. 16). Therefore, the Grade A milk surpluses are not unique to markets where there has been substantial conversion of producers from Grade B to Grade A milk production.

The arguments made by the USDA officials concerning whether it would be feasible to reduce Grade A milk surpluses by lowering Class I differentials were examined using a recursive simulation model of the Wisconsin dairy industry. The quarterly model has equations linking it to the Chicago regional federal milk order (of which Wisconsin is a large part), USDA's price support program and the U.S. manufacturing milk industry. Wisconsin farm Grade A milk prices are determined in the model by pricing equations similar to those used to compute blend prices under the Chicago federal order. Wisconsin Grade B farm milk prices are determined by changes in wholesale cheese prices, wholesale butter price changes, Grade B milk prices lagged one-quarter, and seasonal variables. The current Wisconsin all-milk price, which influences milk production in succeeding quarters, is a weighted average of current Grade A and Grade B milk prices. The change in the percentage of milk produced as Grade A in Wisconsin during the current quarter is determined by the amount by which the Grade A milk price exceeded the Grade B price during the previous quarter and seasonal variables. The Chicago federal order Class I differential is a policy variable which can be manipulated in the model to study the impact of alternative milk-pricing plans. Readers desiring a description of the forty-two equations in the model should consult the publication by Salathe, Dobson, and Peterson.

The model was employed to examine pricing plans designated as I, II, III, IV, and V for the 1969–75 period. Plans I, II, and III involved Chicago federal order Class I differentials of $1.26 (present Class I differential), $.91 (intermediate Class I differential), $.76 (Class I differential employed in 1965), respectively. Pricing Plan I serves as a benchmark against which the effects of the other plans can be compared. Under the benchmark run, USDA price-support purchases of butter and cheese, dairy product imports, and exogenous variables (beef prices, farm wage rates, transportation costs, disposable income, United States all-food price index) were entered into the model at their actual levels to simulate closely the actual situation for 1969–75. Pricing Plan IV is the same as Plan II except that USDA purchases of cheese under the price support program were increased to compensate producers for the reduction in blend prices which would have resulted from lowering the Class I differential to $.91. Pricing Plan V is the same as Plan III except that USDA price support purchases of cheese were increased to compensate producers for the reduction in blend prices caused by lowering the Class I differential to $.76.

Class I price premiums were assumed to remain unchanged as a result of the reductions in Class I differentials under Plans II, III, IV, and V. Admittedly, producers might have negotiated larger Class I premiums to offset the reduction in Class I differentials when competitive conditions in the market and other factors permitted such actions.

The recovery pattern for the all-milk price under Plans II and III to the $8.54 level of the benchmark run by 1975 requires explanation (table 3). This pattern of price recovery does not mean that the long-run marginal revenues for the fluid and manufacturing classes are equal under the model; rather, the price recovery pattern is mainly a supply phenomenon. The lower Class I differentials which be-

Table 3. Simulated Values for Five Variables Computed under Different Pricing Plans, 1969, 1972, and 1975

Variable	Pricing Plan	Years 1969	1972	1975
Percentage of milk produced as Grade A	I	50.6	59.3	67.3
	II	49.4	51.3	54.5
	III	48.8	47.2	48.1
	IV	49.3	51.1	54.3
	V	48.6	47.0	57.8
Class I utilization in Chicago federal order (% Class I)	I	51.7	40.1	32.4
	II	53.4	46.8	40.4
	III	54.3	51.1	46.1
	IV	53.4	46.7	40.3
	V	54.2	50.9	45.9
Wisconsin Grade A milk price ($/cwt.)	I	5.30	5.59	8.75
	II	5.18	5.59	8.81
	III	5.12	5.59	8.83
	IV	5.22	5.60	8.81
	V	5.18	5.60	8.84
Wisconsin Grade B milk price ($/cwt.)	I	4.82	5.04	8.14
	II	4.86	5.11	8.23
	III	4.88	5.14	8.27
	IV	4.91	5.12	8.24
	V	4.95	5.16	8.29
Wisconsin all-milk price ($/cwt.)	I	5.06	5.37	8.54
	II	5.02	5.36	8.54
	III	5.00	5.36	8.54
	IV	5.06	5.37	8.54
	V	5.06	5.37	8.54

came effective under Plans II and III in 1969 caused a small percentage of producers to exit from dairy farming and remaining producers to reduce milk production slightly. Also Class I utilization and Grade B milk prices increased under these plans relative to the situation under the benchmark run. These developments offset the effects of lowering the Class I differentials and caused the all-milk price for Plans II and III to rise to the $8.54 level of the benchmark run by 1975. Also the recovery of the all-milk prices under Plans II and III to the exact level of the all-milk price for the benchmark run in 1975 was atypical. Generally, the model forecasts that the all-milk price will return only to within ±$.01 or ±$.02 per hundredweight of the benchmark price (rather than to the exact level of the benchmark run) following introduction of exogenous changes such as those simulated under Plans II and III.

The simulated increase in Grade B milk prices and reductions in Grade A milk prices under the lower Class I differentials for Plans II through V influenced the percentage of milk produced as Grade A in Wisconsin. For example, although still increasing during 1969–75, the rate of conversion to Grade A milk production was lower under Plan II than under the benchmark run. Thus, in 1975 the percentage of milk produced as Grade A under Plan II was thirteen points lower under the benchmark run. Under Plan III, the percentage of Grade A milk remained nearly constant at 47% to 48% during 1969–75.

The lower Class I differentials associated with Plans IV and V also gave fewer Wisconsin producers incentives to produce Grade A milk. Consequently, in 1975 Class I utilization for the Chicago market under Plan IV was 40% (eight percentage points higher than under Plan I) and 46% (fourteen percentage points higher than under Plan I) under Plan V. Prices for producers who did pool on the Chicago Grade A market under Plans IV and V exceeded by a few cents those of the benchmark run. The all-milk price and milk production were the same under Plans I, IV, and V. Therefore, the gross receipts to Wisconsin milk producers were about the same under the three plans. However, Grade B milk producers received a larger percentage of the receipts under the latter two plans. In addition, some costs associated with producing more Grade A milk than required for fluid uses and needed reserves would have been avoided under Plans IV and V.[7]

The results for Plans II, III, IV, and V fail to lend support to the arguments made by USDA officials regarding the impact of lowering Class I differentials on conversion from Grade B to Grade A milk production. It appears that the United States may be headed inevitably for one grade of milk (Grade A) only if USDA continues present Class I differentials. Moreover, given the results achieved when reductions in Class I differentials were combined with higher dairy price supports, it appears that it might be feasible to make reductions of Class I differentials of the size associated with Plan IV ($.35) and Plan V ($.50). The results achieved under these combinations include avoidance of costs associated with producing more Grade A milk than needed, higher returns for Grade B milk producers, and blend price compensation for producers whose milk is required for the Grade A market.

[7] However, it should be noted that because of the larger price support purchases under Plans IV and V, social costs of the type described by Buxton and Hammond would be higher under these two plans than under Plan I.

Concluding Observation Regarding Norm No. 1

The stability of system average Class I differentials from 1968–75 suggests that USDA did little in this period to further exploit the inelastic demand for fluid milk to enhance producer prices. However, it still is apparent that federal order blend prices during these years exceeded those required to elicit an adequate supply of Grade A milk in markets where there are large numbers of Grade B milk producers (e.g., upper Midwest) and in other areas as well (e.g., the Northeast). Moreover, the simulation experiment suggests that lowering Class I differentials would be effective for reducing the Grade A surpluses. Therefore, reductions in Class I differentials—rather than policies which made permanent the higher Class I differentials adopted when milk supplies tightened temporarily in the late 1960s—were called for in recent years. Hence, USDA's policies with respect to Class I differentials fail to measure up to those specified in Norm No. 1.

Manufacturing Milk Prices Employed under Federal Orders

USDA employs the Minnesota-Wisconsin (M-W) manufacturing milk price, which reflects competitive prices paid for Grade B milk purchased by milk plants in Minnesota and Wisconsin, as the basic manufacturing class (Class III) price for the federal orders. USDA officials interviewed during the study indicated that the M-W price sometimes falls below the price paid for Grade B milk used for cheese production in parts of the Chicago milkshed. On the other hand, regulated handlers in some federal order markets claim that the M-W price is so high that it causes them to incur losses on surplus Grade A milk purchased at the Class III price. Apparently, the processing losses on Class III milk occur most frequently at plants which handlers are unable to operate consistently at high volume, low cost levels because of variation in the availability of milk. However, the USDA officials did not indicate that losses under the present Class III price had become so widespread as to make it difficult for producers to dispose of surplus Grade A milk in the federal order markets. Moreover, if USDA lowered the Class III price to accommodate the handlers who presently may incur losses under the M-W price, this could encourage other federal order handlers to purchase Grade A milk solely for manufacturing purposes. This would reduce the incentive of handlers to serve the fluid market and increase surpluses of Grade A milk. Thus, with the exceptions noted, it appears that the M-W price gives federal order producers the highest return consistent with continuous disposal of Grade A milk in excess of fluid needs as required by Norm No. 3.

Although the M-W price series establishes Class III prices at the level required by Norm No. 3, producers have expressed concern about the increased variability exhibited by the price series in recent years.

Contribution of Federal Milk Orders to Market Stability

The Agricultural Marketing Agreement Act of 1937 specifies that federal milk orders should "establish and maintain such orderly marketing conditions . . . as will provide in the interests of producers and consumers an orderly flow of the supply thereof through its normal marketing season to avoid unreasonable fluctuations in supplies and prices" (U.S. Department of Agriculture 1971, p. 2). Nourse et al. imply that especially in the early years of the federal order program (late 1930s to late 1950s) the orderly marketing provision called for USDA to use federal orders to reduce seasonal gluts and local shortages of milk (pp. 89–98). USDA presently appears to draw authorization for federal order provisions affecting a broad range of competitive and milk marketing practices from this provision. Masson, Masson, and Harris (p. 38) indicate that "orderly marketing" implies an absence of certain competitive practices (e.g., pool loading and predatory practices). The term "unreasonable fluctuations in price" has been interpreted as referring to extreme, erratic, or unpredictable milk price movements (Dobson and Buxton, pp. 18–19).

The impact of federal milk orders on performance was examined using norms which are consistent with certain of the above interpretations of the Act's language. Specifically, federal milk orders were judged to improve market performance if they (*a*) reduced problems associated with extreme seasonal variation in milk production (Norm No. 4), and (*b*) reduced extreme, erratic, or unpredictable price movements (Norm No. 5). In

addition, conditions in the Chicago and Mississippi markets, where federal milk orders were voted out and reinstated in recent years, were examined to gain insights about what happens to "orderliness" in the absence of federal milk orders and to examine implications of USDA's broad interpretation of the "orderly marketing" language of the Act. No assessment was made regarding whether certain types of competitive behavior by cooperatives and milk processors created disorder in the Chicago and Mississippi orders prior to the time these orders were voted out. Neither was an evaluation made of the effectiveness of federal milk orders for dealing with the competitive practices which Masson, Masson, and Harris cited as being incompatible with orderly marketing. These questions involve legal issues which are beyond the scope of this study.

Seasonality of Milk Production

In order to conduct the analysis associated with Norm No. 4, three seasonal milk production indexes were developed. The indexes are based on average daily milk production for the United States for the largely prefederal order period of 1930–39 (USDA 1961), average daily milk-marketing figures for nonfederal order markets for 1965–75 (USDA, *Milk Prod.* 1965–75), and producer receipts figures for federal order markets for 1965–75 (USDA, *FMO Statistics* 1965–75). The monthly indexes for each period were computed by dividing average daily milk production (marketing) figures for each month by the average daily production (marketing) figures for the year and multiplying the result by 100.

The monthly seasonality index computed from United States milk production for 1930–39 varied from a low of 86 for December to a high of 128 in June, a range of 42 points. The index computed from federal order producer receipts for 1965–75 ranged from 94 in November to 110 in May (16-point range). Indexes of seasonality computed from nonfederal order milk production for the United States for 1965–75 varied from 88 in November to 117 in June, a range of 29 points.

There are at least two explanations for the lower seasonal variation exhibited by the federal order milk receipts during 1965–75. First, producers marketing milk under federal orders are larger producers who employ production practices which produce a more even flow of milk year-round (e.g., dry-lot feeding of dairy cattle). Second, mechanisms in the federal orders (e.g., "take out and payback" plans and base-excess plans) gave milk producers price incentives which induced them to reduce the seasonality of milk production in federal order markets. Eleven federal milk orders, representing 39% of the producer receipts in all federal orders, were equipped with "take out and payback" plans in 1975 (USDA, *FMO Statistics* 1975). Nine federal orders representing 18% of the producer receipts pooled under all federal orders, were equipped with base-excess plans in 1975 (USDA, *FMO Statistics*, 1975).

Information obtained from Harris and interviews of USDA officials indicate that the pronounced seasonality of milk production during the prefederal order period of the 1920s and 1930s caused producers to lose markets when milk production increased sharply in the spring and created problems for marketing firms involved in disposing of surplus milk. These same sources suggested that the decline in seasonality of milk production, which federal milk order provisions helped to produce, made milk markets more secure for producers and made it easier for handlers to dispose of milk in excess of fluid needs. Therefore it seems that federal orders have contributed to improved performance as defined in Norm No. 4. However, note that this investigation did not consider whether the benefits obtained from reducing the seasonality of milk production in federal order markets exceed the costs of obtaining such reductions.

Price Variability

According to Harris, milk prices in the prefederal order years of the 1920s and 1930s often rose sharply in the fall and collapsed in the spring. This extreme price variation, often associated with seasonal changes in demand and supply for milk, is uncommon in today's federal order markets. Nonetheless, federal order milk prices—like the prices of many other commodities—exhibited greater variability in the mid-1970s. For example, during 1973–75, the coefficients of variation (computed from monthly average prices) for the M-W price, all-market-average federal-order blend prices, and all-market-average federal-order minimum Class I prices increased to levels 4.2, 1.8, and 3.1 times higher, respectively, than during 1965–72. During 1974–76 producer coopera-

tives explored with USDA using different federal milk-order pricing mechanisms which, among other things, would produce more stable milk prices. Producers took this step partly because they feared a repetition of the 1974–75 situation, when federal milk order prices fell sharply while milk production costs rose. As of early 1978, nothing had developed from this initiative. However, the fact that it occurred suggests that producers doubted their ability to forecast and adjust adequately to the more extreme price variation of the type prevailing in 1974–75.

The increased volatility of federal order prices during 1973–75 occurred mainly because of greater variability exhibited by the M-W basic formula price. Federal orders, as presently written, do little to insulate Class I, Class II, Class III, and blend prices from any extreme variation in the M-W milk price, because the class prices of the orders are linked to this price by fixed differentials. Thus, the orders presently fail in one respect to produce the performance called for in Norm No. 5.

According to milk handlers interviewed, processors in deficit southern federal order markets in the 1950s and 1960s sometimes found it necessary to pay $3.00 or more per hundredweight over local market Class I prices for supplemental milk delivered to their plants from other markets when milk supplies became short. The increases in Grade A milk surpluses and increased Grade A milk reserves in federal order markets have produced supply situations which cause extreme variation in prices of supplemental fluid milk to be less common today. According to Norm No. 5, this development represents an improvement in performance. Thus, the benefits obtained from more stable prices for supplemental milk may offset some costs associated with the increased Grade A milk surpluses.

USDA removed "supply-demand" adjustors from about sixty federal orders during 1968–71. Supply-demand adjustors are mechanisms that produce automatic increases (decreases) in Class I prices when Class I utilization increases (decreases). USDA officials questioned during the study indicated that these devices had, at times, produced erratic Class I price adjustments which failed to reflect supply and demand forces in the integrated system of markets. Also, the supply-demand adjustments apparently had impaired Class I price alignment and created questionable raw product cost advantages for handlers in some markets (Babb, Banker, Nelson, p. 13). Thus, USDA's decision to eliminate these mechanisms, which failed to work well in an interdependent market system, apparently produced performance improvements of the type called for in Norm No. 5.

Therefore, in federal order markets, the disorder and price instability associated with seasonal variations in milk production are lower than in the past. However, some extreme, erratic, and unpredictable milk price variation has arisen from other sources (e.g., more variable manufacturing milk prices and supply-demand adjustors) in recent years. USDA has been partially successful in dealing with the price instability arising from these other sources.

Changes in "Orderliness" in the Absence of Federal Milk Orders

When the Chicago federal milk order was voted out by producers during May 1966–June 1968, conditions remained relatively stable because many former Chicago order plants pooled under the Milwaukee order, and producer cooperatives operated a "quasi-order" which performed many classified pricing, pooling, and auditing functions previously carried out under the federal order. Under the quasi-order, producers negotiated a $4.85 average Class I price for the twelve-month period immediately following termination of the Chicago order. This Class I price was only $.05 per hundredweight (1%) less than the Class I price which would have prevailed if the Chicago federal order had operated during the twelve-month period (USDA 1968, p. 7517). But within a year after termination of the Chicago order, producers became concerned that the voluntary pricing and pooling arrangement would collapse. Therefore, they asked USDA to restore the order. USDA's response said "it is quite possible this (voluntary classified pricing and pooling) arrangement could break down. If this should happen, whatever orderly marketing this voluntary pool brought to Chicago would completely disappear" (USDA 1968, p. 7517). The agency then reinstated the order in July 1968.

Conditions were less stable when the Mississippi order was voted out by producers for the period May 1973–March 1976. In the absence of the order, "flat" pricing reappeared—one cooperative (Dairymen, Inc.) found itself handling a larger share of the

reserve Grade A milk for the market after local cheese manufacturing plants curtailed purchases of surplus Grade A milk in response to the 1974 buildup in national cheese inventories, sharp variations in prices paid to producers by individual handlers developed as fluid milk sales shifted from handler to handler within the market, milk producers shifted from dealer to dealer, and producers claimed that handlers were engaging in unfair competitive practices. Regarding competitive practices, the spokesman for one small cooperative said that when the order was out of existence "milk (from outside Mississippi), which otherwise would be used for manufacturing purposes, was being brought into Mississippi and displacing the Class I sales of local dairymen" (USDA 1975, p. 50052). He held that "a federal order is needed to regularize the marketing of milk in Mississippi" (USDA 1975, p. 50052).

USDA, in its decision to restore the order, indicated that it regarded developments in Mississippi as disorderly. A federal milk order, equipped with classified pricing and marketwide pooling provisions, possesses the inherent capacity to eliminate "disorder" of the type which surfaced in Mississippi; hence, USDA's decision to restore the milk order might be considered appropriate. However, some developments which were characterized as "disorderly" in Mississippi are expected happenings in competitive markets (e.g., the shifting of producers from one plant to another in response to price incentives). Moreover, the testimony that a federal order was needed to "regularize" milk marketing in Mississippi appeared to be a thinly veiled request for market protection. Therefore, some of what has been identified as disorder in this market might not have been disorder.

The decisions for the Chicago and Mississippi cases suggested to us that USDA, with few explicit qualifications, interprets "orderly marketing" as being broadly synonymous with the market performance produced by classified pricing. At a minimum, this interpretation lacks precision. For example, it fails to recognize adequately that performance ranging from that associated with the stability objective to that associated with the price enhancement objective arises under classified pricing. Also, there appears to be no justification for sanctions of market protection under the guise of promoting "orderly marketing." Therefore, USDA might find it worthwhile to reexamine the broad interpretations which it presently gives to "orderly marketing."

Characteristics of U.S. Fluid Milk Markets Absent Regulation

What does the information developed in the article suggest about what fluid milk markets would be like in the absence of federal orders? Chicago cooperatives showed that they could develop pricing and pooling mechanisms to replace federal orders. Could cooperatives develop a system of substitute orders? March reports that in 1974 about 88% of the producers supplying the federal order markets were members of cooperatives and the ten largest cooperatives represented about 55% of all producers in the federal order markets. Moreover, producers in federal order markets have demonstrated their ability for joint action by operating the standby pool (Cook 1970), presenting joint proposals at federal order hearings and by negotiating multimarket Class I premiums. Therefore, to the extent that ability to develop quasi-orders depends on potential control over milk supplies and ability to engage successfully in collective action, it appears that other cooperatives might be able to develop pricing and pooling mechanisms similar to those employed by producers in the Chicago market in 1966–68. Moreover, governments of eighteen states have authority through milk commissions, state milk orders, or similar devices to establish minimum prices to be paid milk producers (Manchester, p. 11). Thus, quasi-orders similar to the present federal orders might emerge if cooperatives or state governments were permitted by the courts to fill voids left by elimination of federal orders. However, any such system might be a "patchwork" of regulations because neither the states nor the cooperatives could provide the systemwide coordination provided by federal orders.

If federal milk orders were eliminated and cooperatives and state governments were prevented from developing replacements for the orders, then there might emerge a system where (*a*) Class I differentials would fall, (*b*) the conversion from Grade B milk production to Grade A milk production in the upper Midwest, in particular, would slow, (*c*) surpluses of Grade A milk would decline, (*d*) manufacturing milk prices would rise, (*e*) fluid milk prices would become more variable, and (*f*)

"disorder" similar to that which emerged in Mississippi when the order for that market was voted out might surface.

As suggested earlier—especially by results of the simulation analysis—the decline in Class I differentials would generate developments (*b*), (*c*), (*d*), and (*e*). How far would Class I differentials fall in the absence of orders or similar devices? This would vary from market to market. Competition among milk producers probably would reduce the component of the Class I differential that reflects exploitation of the inelastic demand for fluid milk. As Cook (1977) points out, local health inspection laws now provide little protection to local producers from producers in other markets who may wish to dump surplus Grade A milk in their market. In this environment, competition for Class I sales might make it difficult to maintain present Class I differentials in the absence of orders or quasi-orders. However, over the longer run, Class I prices would remain above manufacturing milk prices in order to compensate producers for the added cost of producing Grade A milk and to attract needed fluid milk supplies to markets especially during seasons of highest fluid milk demand.

The forecasts concerning what milk markets would be like in the absence of federal milk orders are based mainly on inferences drawn from findings of the present study. The results appear to be consistent with how fluid milk markets functioned prior to introduction of federal order in the 1930s and during the temporary absences of regulation in the Chicago and Mississippi fluid milk markets. Presumably, different forecasts regarding the effects of eliminating the orders would emerge if scenarios representing a greater departure from the past were considered. It might be useful if subsequent research examined such alternative scenarios.

Summary and Implications

This study indicates the following points: (*a*) Although USDA kept Class I differentials nearly constant during 1968–75, the agency's pricing policies failed to conform to those called for by Norm No. 1. This norm suggested that USDA should have reduced federal order minimum Class I differentials and made efforts to reduce certain persistent Class I premiums in recent years.

(*b*) Contrary to policies called for in Norm No. 2, USDA established in the late 1960s Class I differentials for the Chicago federal order market which induced some producers whose milk was not required for the fluid market to convert from Grade B to Grade A milk production. As required by Norm No. 3, USDA has established a Class III price for federal orders which generally gives producers the highest return consistent with continuous disposal of Grade A milk in excess of fluid needs. Federal milk orders have helped to reduce the pronounced seasonality of milk production in federal order markets. This contributed to the performance called for in Norm No. 4.

(*c*) As required by Norm No. 5, federal milk orders have improved performance by reducing certain types of erratic and extreme price variation (e.g., that associated with prices of supplemental milk and supply-demand adjustors). However, as presently written, federal orders do little to reduce extreme price variation that arises because of variation in the Minnesota-Wisconsin basic formula price. If price variation of the type which emerged in 1973–75 becomes common, then USDA may need to develop federal order pricing mechanisms that produce less variable prices.

(*d*) USDA interprets the concept of "orderly marketing" as being broadly synonymous with market performance expected under classified pricing. This interpretation lacks precision because it fails to recognize adequately that performance ranging from that associated with the stability objective to that associated with the price enhancement objective arises under classified pricing.

(*e*) Quasi-orders similar to federal orders might emerge if cooperatives or state governments were permitted to fill voids created by elimination of federal milk orders. If cooperatives and state governments were prohibited from replacing federal milk orders, then fluid milk markets with lower Class I differentials, more variable fluid milk prices, and smaller Grade A milk surpluses might develop.

[*Received September 1977; revision accepted October 1978.*]

References

Babb, E. M., D. E. Banker, and G. L. Nelson. *Price Relationships Among Federal Milk Marketing Orders*. Purdue University Agr. Exp. Sta. Bull. 146, Nov. 1976.

Burk, Marguerite C. *Consumption of Dairy Products—An Analysis of Trends, Variability, and Prospects*. University of Minnesota Agr. Exp. Sta. Tech. Bull. 268, 1969.

Buxton, Boyd M. "Welfare Implications of Alternative Classified Pricing Policies for Milk." *Amer. J. Agr. Econ.* 59(1977):525–29.

Buxton, Boyd M., and Jerome W. Hammond. "Social Cost of Alternative Dairy Price Support Levels." *Amer. J. Agr. Econ.* 56(1974):286–91.

Capper-Volstead Committee. "The Question of Undue Price Enhancement by Milk Cooperatives." Unpublished paper, USDA, Washington, D.C., Dec. 1976.

Cook, Hugh L. "Federal Order Pricing of Milk Under Fire." *Econ. Issues*. Dep. Agr. Econ., University of Wisconsin, Jan. 1977.

———. "The Standby Milk Pool—A New Strategic Bargaining Device." *Amer. J. Agr. Econ.* 52(1970):103–8.

Cook, Hugh L., Leo Blakley, and Calvin Berry. *Review of Eisenstat, Philip, Robert T. Masson, and David Roddy, "An Economic Analysis of the Associated Milk Producers, Inc., Monopoly."* University of Wisconsin Res. Bull. R2790, Jan. 1976.

Cummins, David E. *Comparison of Production Costs of Grade A and Grade B Milk*. USDA ESCS Rep. 05, Jan. 1978.

Deiter, R. E., J. W. Gruebele, and E. M. Babb. "Services Provided by Dairy Cooperatives and What They Cost." Paper presented at Midwest Milk Marketing Conference, Columbus, Ohio, 23–24 Mar. 1976.

Dobson, W. D., and Boyd M. Buxton. *An Analysis of the Effects of Federal Milk Orders on the Economic Performance of U.S. Milk Markets*. Res. Bull. R2897, University of Wisconsin, Oct. 1977.

Eisenstat, Philip, Robert T. Masson, and David Roddy. *An Economic Analysis of the Associated Milk Producers, Inc., Monopoly. United States* v. *Associated Milk Producers, Inc.*, 394 Fed. Supp. (29 W.D. No. 1975) affirmed, 534 F.2d 113 (8th Cir. 1976).

Frank, Gary G., G. A. Peterson, and Harlan Hughes. "Class I Differential: Cost of Production Justification." *Econ. Issues*. Dep. Agr. Econ., University of Wisconsin, Apr. 1977.

George, P. S., and G. A. King. *Consumer Demand for Food Commodities in the United States with Projections to 1980*. Giannini Foundation Monograph No. 26., University of California, Berkeley, Mar. 1971.

Halvorson, H. W. "Response of Milk Production to Price." *J. Farm Econ.* 40(1958):1101–13.

Harris, Edmund S. *Classified Pricing of Milk: Some Theoretical Aspects*. USDA AMS Mktg. Res. Div. Tech. Bull. 1184, Apr. 1958.

Ippolito, Richard A., and Robert T. Masson. "The Social Cost of Government Regulation of Milk." *J. Law and Econ.*, in press.

Kennedy, Edward M. "Address of Senator Edward M. Kennedy at the Conference on Milk Prices and the Marketing System." Proceedings, Community Nutrition Institute, Washington, D.C., 1976.

Manchester, Alden C. *Milk Pricing*. USDA ERS Agr. Econ. Rep. 315, Nov. 1975.

March, Robert W. "Memo to All Market Administrators on Cooperatives in Federal Milk Order Markets." USDA AMS Dairy Div., 19 Aug. 1975.

Masson, Alison, R. T. Masson, and B. C. Harris. "Cooperatives and Marketing Orders." Paper presented at NC-117 sponsored Workshop on Agricultural Cooperatives and the Public Interest, St. Louis, Mo., 6–8 June 1977.

Nourse, E. G., et al. *Report to the Secretary of Agriculture by the Federal Milk Order Study Committee*. USDA, Dec. 1962.

Rojko, Anthony D. *The Demand and Price Structure for Dairy Products*. USDA Tech. Bull. 1168, 1957.

Rosenbury, John B. "The Milk Problem—1976." Unpublished paper. USDA AMS Dairy Div., Rochester, Minn., Mar. 1976.

Salathe, L., W. D. Dobson, and G. Peterson. "Using a Dairy Industry Model to Simulate the Impact of Alternative U.S. Dairy Import Policies on Wisconsin's Dairy Industry." Agr. Econ. Staff Pap. No. 122, University of Wisconsin, Feb. 1977.

U.S. Department of Agriculture. *Compilation of Agricultural Marketing Agreement Act of 1937, with Amendments as of January 20, 1971*. CMS Agr. Handbook 421, Oct. 1971.

———. *Federal Milk Order Market Statistics* (*FMO Statistics*). AMS Dairy Div., annual summaries 1955–76.

———. *Federal Order Class I Prices and Announced Cooperative Class I Prices in 31 Selected Cities* (*Class I Premiums*). AMS Dairy Div., July 1973–Dec. 1976.

———. *Fluid Milk and Cream Report*. SRS (*FMC Rep.*), monthly issues, Jan. 1965–June 1973.

———. "Milk in Chicago, Illinois and Certain Other Marketing Areas, Partial Decision on Proposed Amendments to Tentative Marketing Agreements and to Orders." *Federal Register*, vol. 33, no. 99, 21 May 1968.

———. *Milk Cows on Farms, Production Per Cow, and Total Production by Months, 1930–59*. SRS CRB Statist. Bull. 289, June 1961.

———. "Milk in New Orleans, Louisiana Marketing Area, Recommended Decision and Opportunity to File Written Exceptions on Proposed Amendments to Tentative Marketing Agreement and to Order." *Federal Register*, vol. 40, no. 208, 28 Oct. 1975.

———. *Milk Production, Disposition, and Income, 1965–66*. SRS Da 1-2(67), Apr. 1967.

———. *Milk Production* (*Milk Prod.*), various issues for 1965–75.

Wilson, Robert T., and Russell G. Thompson. "Demand, Supply, and Price Relationships for the Dairy Sector, Post-World War II Period." *J. Farm Econ.* 49(1967):360–71.

Wipf, L., and J. P. Houck. "Milk Supply Response in the United States—An Aggregate Analysis." Agr. Econ. Rep. 532, University of Minnesota, July 1967.

The Influence of Consumer Price Information on Retail Pricing and Consumer Behavior

D. Grant Devine and Bruce W. Marion

Comparative price information for major Ottawa supermarkets was collected over a twenty-eight-week period and published in daily newspapers during a five-week test period. In response to the information, the dispersion of prices across stores and chains narrowed, the average level of prices of the market dropped, and consumer satisfaction increased relative to the control market. Consumers transferred patronage to the lower priced stores. Consumers indicated a willingness to pay 34¢ per week on average for the price comparison information. Estimated consumer benefits far exceeded the cost of the program.

Key words: competition, consumer benefit, food prices, food retailing, information.

This article reports the results of research in which the authors had the rare opportunity to manipulate the variable of interest—market information (retail food prices)—and to monitor the effects. Contrary to conventional assumptions, it was assumed that consumers have inadequate information with which to choose rationally among retail food stores and hence are unable to express accurately their preferences in the market place. The research examined the influence of increased comparative price information (provided by a public agency) on the level and dispersion of retail food prices and the level of consumer satisfaction. Perceived and estimated benefits of the information program were also assessed.

Theoretical Effects of Information

Most economic models assume (implicitly or explicitly) that market participants have adequate information for rational decision making. Notwithstanding the work of Stigler, Diamond, Rothschild and Salop, few economists have considered the theoretical consequences of inadequate information or of altering the level of market information. Existing theoretical treatments of market information also have concentrated on competitive markets; the theory of information in imperfectly competitive markets approaches a zero set.

Conceptually, market information is an element of market structure, may influence other structural dimensions (concentration, entry conditions, and product or enterprise differentiation), and also affects market conduct and performance. Of particular interest in the study reported here is the effect of price information on two aspects of allocative efficiency—price dispersion and price level—and on consumer satisfaction.

Expected Effects on Price Dispersion and Price Levels

In one of the early articles on information, Stigler emphasized that price dispersion is "ubiquitous even for homogeneous goods" and contended that the degree of price dispersion for homogeneous goods depends upon the level of buyer search.

In a homogeneous product market, price dispersion represents an undesirable imperfection. In such markets, the dissemination of additional price information is expected to reduce price dispersion and, if competition is effective, to lower price levels toward margi-

D. Grant Devine is associate professor of agricultural economics, University of Saskatchewan, and Bruce W. Marion is an agricultural economist with ESCS, USDA, and adjunct professor, University of Wisconsin.

Research for this article was conducted when both authors were at Ohio State University.

This article does not necessarily reflect the view of the U.S. Department of Agriculture.

nal costs. The results of increased information are theoretically predictable.

In markets with differentiated product-service offers, some degree of price dispersion is expected if buyers perceive alternative offers as imperfect substitutes. The concern in these markets is not whether price dispersion exists, but whether price differences reflect buyer preferences and seller costs. Inadequate price information is expected to result in price dispersions which do not accurately reflect differences in costs and preferences. However, it is theoretically impossible to predict whether price dispersions will be too wide or too narrow and hence to posit the expected effect of increased price information on price dispersion.

Theory provides somewhat more guidance concerning the expected effect of information on price levels in differentiated product markets. To the extent that increased price information erodes elements of market power, such as entry barriers, an information program likely would lead to lower prices. In an underinformed market, increased information also is likely to shift the competitive emphasis. When price information is poor and perceived store price differences are slight, consumers are expected to rely heavily on nonprice factors (store location, cleanliness, product selection, customer service, etc.) in selecting a store. Increased price information is expected to reverse this phenomenon—at least until the distribution of prices reaches a new equilibrium. Consumers are likely to become more sensitive to price in selecting stores; individual retailers will find the demand curve they face has shifted and become more elastic, encouraging price competition. At least in the short run, prices are expected to decline.

The above provides modest support for hypothesizing a drop in price levels in differentiated product markets when a price information program is initiated. The effect of such a program on price dispersion cannot be hypothesized, however.

Expected Effects on Consumer Satisfaction

The level of consumer satisfaction provides one measure of what Henderson has called "allocative accuracy." Allocative accuracy refers to the extent to which demand preferences and supply offerings match in terms of the quantity, quality and price of products, and the location and timing of production and marketing. Marion and Handy have proposed direct measures of consumer satisfaction as indicators of the degree of "match" between actual supply offerings and the preference schedules of consumers.

Increased price information is expected to effect positively consumer satisfaction in several ways. Increased information should reduce the search time and the uncertainty of store selection decisions for individual consumers. Because consumers should be able to reveal more accurately their preferences through their store selection decisions, allocative accuracy would tend to be improved. At least in the long run, this should enhance consumer satisfaction. If price information reduces the level of prices, as hypothesized above, this also would be expected to increase consumer satisfaction unless preferred services or product quality are sacrificed in the process. Thus, a price information program is hypothesized to have a positive effect on consumer satisfaction.

Research Design

A pretest, post-test control-group research design was employed. Two Canadian metropolitan areas, Ottawa-Hull and Winnipeg, were used as test and control markets, respectively. Prices were collected weekly by trained enumerators on sixty-five food products in twenty-six supermarkets in the test market and in six supermarkets in the control market. The sixty-five food items were selected to represent adequately the major food categories of meat, fresh fruits and vegetables, dairy products, canned fruits and vegetables, major beverages, and cooking materials. A weighted price index (using expenditure weights) for the sixty-five item market basket was calculated each week for each store and each chain.

There were three phases of the study, all of which were done under the auspices of the Food Price Review Board of Canada. Phase I was a seventeen-week preinformation period during which prices in test market stores were collected and summarized but not published. Surveys of consumer satisfaction and shopping behavior in the test and control markets were also conducted. To improve the response rate normally associated with a mail questionnaire and simultaneously to avoid the cost of personal delivery and pickup, a premailing telephone survey was employed to identify

consumers willing to participate in the study. (Manitoba Government Telephones estimates that 95% of the households in the Winnipeg market have telephones. Bell Canada estimates that 99% of the households in Ottawa-Hull had telephones in 1976.)

Questionnaires were sent to 1,800 Ottawa consumers beginning the latter part of June. After a follow-up letter in mid-July, the final response rate was higher than 60%; 1,137 questionnaires had been completed and returned. Questionnaires were sent to 1,500 Winnipeg consumers in mid-July; 743 were returned by the first week in August.

Phase II was a five-week information period during which prices were collected weekly in both the test and control market supermarkets. Comparative price information on one-half of the individual items and for a weighted market basket was published weekly in the test market through daily newspapers and by direct mail to the sample of consumers participating in the Phase I survey of consumer satisfaction. Prices in the control market were collected but not published.

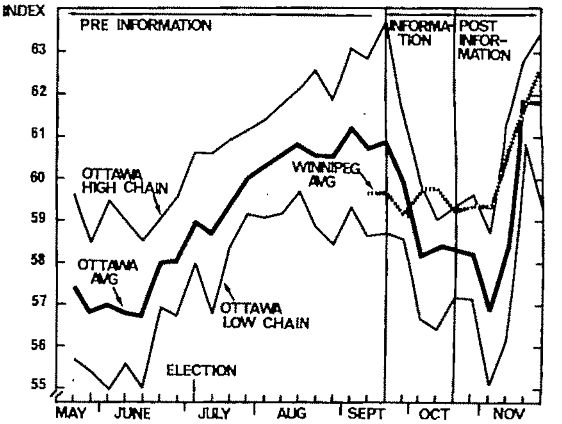
Phase III was a six-week postinformation period during which prices in both test and control markets were collected and summarized but not published. Post-test surveys of consumer satisfaction and shopping behavior were conducted in November in both markets. Questionnaires were sent to the 1,137 Ottawa consumers and 743 Winnipeg consumers who responded to the Phase I survey. Usable responses were received from 507 and 363 consumers, respectively.

Major study hypotheses were: (*a*) significantly different prices for a standardized market basket of food products would be charged by competing sellers prior to the dissemination of comparative price information. (*b*) The public dissemination of comparative price information would alter the dispersion of prices across stores and lower the average market price level in the test market. (*c*) The level of consumer satisfaction with food stores and food products would increase significantly in the test market as a result of the comparative price information program. (*d*) The perceived and estimated value of comparative price information would exceed the cost of providing such information.

Findings

During the preinformation monitoring period, retail food prices rose steadily and reached a peak immediately prior to the information program (fig. 1 and table 1). Statistically significant differences were found between the mean prices of the individual stores, between the mean prices of different chains, and between the mean prices in submarkets within the metropolitan area of Ottawa-Hull using analysis of variance (tables 2, 3, and 4).

Subsequent to the publication of comparative price information, average food prices declined 1.5% the first week, 3.0% the following week, and then remained relatively steady for the next three weeks (fig. 1 and table 1).[1] An additional price decline of 2.5% occurred during the week of 2 November, bringing the total decline over a six-week period to 7.1%. The price declines during the first, second, and sixth week after the start of the comparative price information program were greater than any price declines that occurred during the preinformation period. Mean prices in the Ottawa-Hull market were significantly lower midway through and immediately following the information program. As might be expected, the higher priced stores dropped prices more than relatively low priced stores. Similarly the higher priced chains reduced their prices more than the lower priced chains



Source: Food Prices Review Board Survey 1974, table 5.

Figure 1. Average weighted store price index levels for selected supermarkets, Ottawa-Hull and Winnipeg, 1974

[1] Prices were collected on Thursday, Friday, or Saturday and published in daily newspapers the following Thursday. Thus, on Thursday, 19 Sept., the first price comparisons were published and were for the week ending 14 Sept. Since retailers could not adjust their prices until the week after publication, retailer response to the comparison of prices in effect during the week of 14 Sept. was not evident until the week ending 28 Sept.

Table 1. Average Weekly Store Price Index Levels All Stores Ottawa-Hull and Winnipeg Plus High-Low Extremes for Ottawa-Hull, 1974

			Ottawa-Hull By Firm			Ottawa-Hull By Store		
Date	Average Price Index Winnipeg	Average Price Index Ottawa	Low Chain or Group	High Chain or Group	Percentage Difference	Low Store	High Store	Percentage Difference
May 19		57.41	55.62	59.60	6.67	53.23	61.46	7.87
May 26		56.81	55.36	58.43	5.25	54.81	59.44	7.78
June 2		56.93	54.98	59.46	7.53	53.61	61.37	12.64
June 7		56.81	55.56	58.98	5.47	54.35	59.57	7.63
June 14		56.75	54.99	58.49	5.98	54.32	59.59	8.84
June 21		57.99	56.91	59.05	3.94	56.36	59.95	6.04
June 28		58.09	56.70	59.60	4.86	55.91	60.13	7.01
July 5		58.99	57.99	60.74	4.52	57.65	62.91	8.36
July 12		58.65	56.73	60.69	6.52	56.49	62.90	10.19
July 19		59.30	58.31	60.94	4.31	57.27	62.22	7.95
July 26		59.94	59.11	61.18	3.38	57.34	62.93	8.88
Aug. 2		60.30	59.09	61.34	3.81	58.32	63.19	7.70
Aug. 9		60.58	59.18	61.75	4.32	58.76	62.84	5.82
Aug. 16		60.80	59.70	62.14	3.92	58.56	62.88	6.87
Aug. 23		60.60	58.81	62.58	6.02	58.09	63.71	8.82
Aug. 30		60.55	58.41	61.92	5.66	57.98	63.91	9.27
Sept. 7		61.15	59.37	63.07	5.86	58.38	65.59	10.99
Sept. 14[a]	59.67	60.74	58.61	62.90	6.96	57.71	66.30	12.95
Sept. 21[a]	59.70	60.89	58.70	63.70	7.84	57.59	67.78	15.03
Sept. 28[a]	59.17	59.96	58.57	61.69	5.05	58.24	63.42	8.16
Oct. 5[a]	59.73	58.12	56.61	59.83	5.38	55.98	60.73	7.82
Oct. 12[a]	59.73	58.37	56.42	59.01	4.38	56.37	59.58	5.38
Oct. 19	59.29	58.29	57.18	59.37	3.68	55.60	60.93	8.74
Oct. 26	59.31	58.22	57.13	59.66	4.24	55.24	60.33	8.43
Nov. 2	59.35	56.85	55.17	58.72	6.04	54.17	59.87	9.52
Nov. 9	60.54	58.35	56.19	61.27	8.29	55.07	62.29	11.59
Nov. 23	61.78	61.85	60.86	62.79	3.07	59.97	63.77	5.95
Nov. 30	62.57	61.77	59.50	63.39	6.36	58.79	63.89	7.98

Source: Food Prices Review Board Survey, 1974.
[a] Weeks for which Ottawa prices were published during the following week.

(table 3). The difference in price index levels between high and low priced stores dropped from a maximum of 15% during the pre-information period to a low of 5.4% after the publication of information (table 1). During the same period, the range of prices between high and low priced chains declined from a maximum of 7.3% to a low of 3.1%.

Table 2. Analysis of Variance of Food Price Index Levels for Individual Stores during Selected Time Periods, Ottawa-Hull, 1974

		Price Index Range			
Time Period/ Selected Statistics	Mean Price Index	Low Store	High Store	Percentage Difference	F Value
a. Pre-election period 19 May to 28 June	57.25	55.01	59.97	8.66	12.42[a]
b. Postelection preinformation 5 July to 21 September	60.20	57.70	63.55	9.71	12.73[a]
c. Immediate information period 28 September to 26 October	58.59	57.40	61.98	7.83	2.18[a]
d. Entire survey period 19 May to 9 November[b]	58.89	56.70	61.06	7.40	11.18[a]

[a] Significant at the 99% level of confidence.
[b] Although the Food Price Review Board collected price data during the weeks of 23 November and 30 November, it would not release data to the authors on individual stores. For this reason, the significance of price differences during the post-information period could not be examined. The Board did release data on the price index of the high and low stores and chains for these weeks, however (table 1.).

Table 3. Average Food Price Indices for Voluntary or Corporate Chains during Pretest and Post-test Periods, Ottawa-Hull, 1974

	Preinformation Price Indices (19 May to 21 Sept.)	Information and Postinformation Price Indices (28 Sept. to 9 Nov.)	Change in Price Index	
			Absolute	Percent
IGA	60.81	59.41	−1.40	−2.30
Dominion	57.64	57.16	−0.48	−0.80
Loblaws	59.70	59.18	−0.52	−0.87
A&P	60.31	58.73	−1.58	−2.61
Steinbergs	58.23	57.67	−0.56	−0.96
A.L. Raymond	59.50	57.82	−1.68	−2.82
Range	3.17	2.25		
F value, analysis of variance	9.51[a]	3.85[a]		

Source: Food Prices Review Board Survey, 1974.
[a] Statistically significant at 99% confidence level.

It should be noted, however, that the dispersion of prices in the market reached its high during the week ending 21 September, the first week of publishing comparative price information but before initial retailer response. It is more appropriate to compare the average range of prices during the twelve weeks prior to the information program (9.71%) to the range in prices during the information program (7.83%). The decline in the dispersion of prices was statistically significant at the 90% level based upon an *F* test of the difference in normalized variances.

Within two weeks after the termination of the public information program, average retail food prices in the test market began to rise and increased 8.8% by the end of the research period.

Although there were statistically significant declines in the overall price level and in the price dispersion among stores, significant differences between the price level of individual retail outlets remained during the information period (table 2). The differences in the average prices of individual chains declined but also remained statistically significant (table 3). Dominion and IGA maintained their positions as the low and high priced chains, respectively.

It was expected that the lack of information might be particularly detrimental in low income areas where a lower level of consumer search is less able to police competition. Price data supported this expectation. Ottawa South and Gatineau-Hall, the lower income areas, had significantly higher prices during the preinformation period than Ottawa East, a higher income area (table 4). During the information program, prices in Gatineau-Hull dropped by 4%, to make it the lowest priced of the four areas. Statistical tests, however, revealed no significant difference in the prices in the four areas during the post information period.

Average prices in the control market (Winnipeg) were relatively stable during the test market information period (prices declined 0.6% compared to 7.0% in the test market). During the postinformation period, average prices in Winnipeg increased 5.4% (compared to 8.8% in test market). The cost of the market

Table 4. Store Price Levels by Geographic Area during Pretest and Post-test Period, Ottawa-Hull, 1974

Area	Income per Family ($)	Preinformation Average Price Index	Information and Postinformation Average Price Index	Percentage of Change
Ottawa West	12,890	60.08	58.07	−3.34
Ottawa South	10,540	60.60	59.27	−2.19
Ottawa East	12,561	59.29[a]	58.27	−1.95
Gatineau-Hull	9,508	60.32	57.93	−3.96

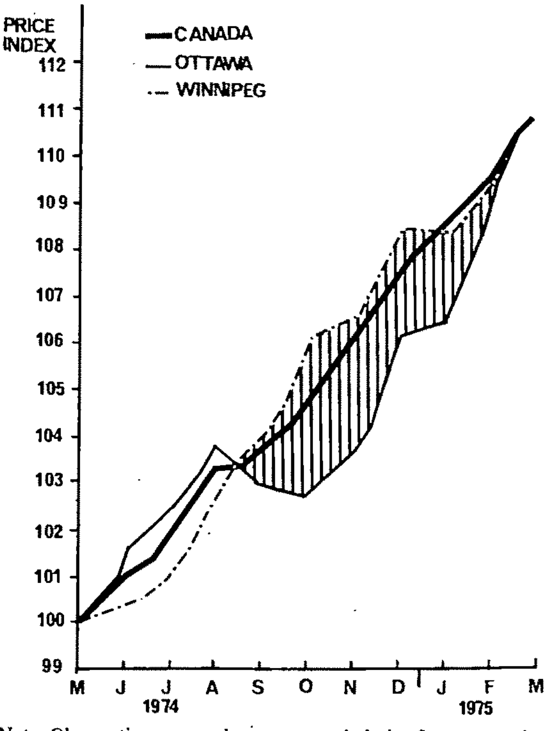
Source: Food Prices Review Board Survey Data, 1974.
[a] Significantly different at the 95% confidence level.

basket was 2% higher in the test market than in the control market at the beginning of the information period. During the final week monitored, prices were 1.3% lower in the test market. Thus, although the sharp price increases in the test market during the post-information period offset the price reductions sustained during the information period, prices in the test market relative to prices in the control market were 3.3% lower at the end of the study than at the start of the information program. The Canadian Consumer Price Index, constructed by Statistics Canada, reflected the price changes that occurred in Ottawa and Winnipeg during this period (fig. 2).

On average, stores changed prices each week on 43% of the items price-checked. The frequency of price changes was surprisingly similar for different chains, ranging from 40.6% for Dominion to 46.5% for Loblaws. Higher priced firms tended to change prices slightly more often than lower priced firms. This may have been largely in response to the price comparison program, as higher priced stores and firms dropped their prices to become "competitive."

Half of the items included in the market basket were identified in the weekly publishing of comparative prices. Because the identity of the remaining items in the market basket were never revealed, it was expected that price adjustments by retailers necessarily would be made on a broad range of products.

Changes in the price index for published items were compared with changes in the price index of nonidentified items. The price index for published items declined 5.8% during the information period compared to 7.8% for the unidentified items. The price index for the published items then increased by 9.8% by the end of the study compared to a 5.6% increase for unidentified items. Statistical tests (*t* test) revealed no significant difference in the price level changes or the frequency of price changes made in the two groups of items.



Note: Observations are made once a month during first two weeks of each month.
Source: Statistics Canada.

Figure 2. Consumer price index for food consumed at home, May 1974 to March 1975 (May 1974 = 100)

Results of Consumer Satisfaction Surveys

Table 5 summarizes the pretest and post-test surveys of consumer satisfaction in the test and control markets. Possible scores range from 1.00 if all consumers surveyed indicated they were "always satisfied" to 5.00 if all consumers said they were "never satisfied". Because higher scores indicate higher levels of dissatisfaction, we refer to the scores as "Mean Dissatisfaction Scores."

An examination of the first column of scores in table 5 indicates that Ottawa consumers were generally quite satisfied with both food products and food stores during the pretest period. With respect to information provided by food stores, consumers were moderately satisfied with the information in stores about prices (MDS of 2.77) and the reliability and truthfulness of advertisements sponsored by stores (MDS of 2.81). They were least satisfied with information about the freshness of perishable food products (MDS of 3.26), with manufacturer advertising (MDS of 3.27), and nutritional labeling (MDS of 3.32).

Although consumers were, on average, "almost always satisfied" with their ability to choose between stores (MDS of 2.08), they were less satisfied with the information available for making store comparisons (MDS of 2.91). When asked, "How often could you use additional information to help you compare products and choose between stores?" 21% said always, 32% almost always, and 36% said

Table 5. Levels of Consumer Satisfaction during Pretest and Post-test, Ottawa-Hull and Winnipeg, 1974

	Ottawa-Hull Pretest	Ottawa-Hull Post-test	Winnipeg Pretest	Winnipeg Post-Test	Change in Ottawa Relative to Change in Winnipeg (%)
1. Food products in general	2.42	2.36	2.18	2.26	6.14
2. Ingredient labeling	2.50	NA	2.46	NA	
3. Manufacturers' advertising	3.27	NA	3.11	NA	
4. Nutritional labeling	3.32	NA	3.10	NA	
5. Food stores in general	2.52	2.49	2.23	2.24	1.64
6. Instore price information	2.77	NA	2.23	NA	
7. Store advertisements	2.81	NA	2.52	NA	
8. Information about freshness	3.26	NA	2.71	NA	
9. Food store prices	3.47	3.40	3.28	3.36	4.46
10. Store services	2.52	2.50	2.13	2.25	6.42
11. Clerk friendliness	2.29	2.20	1.93	1.96	5.48
12. Store cleanliness	2.23	2.21	1.89	1.96	4.60
13. Selection of foods	2.23	2.37	1.91	2.13	6.51
14. Speed of checkout	3.16	3.12	2.45	2.60	7.40
15. Store layout	2.20	2.21	1.91	1.99	3.74
16. Parking space	1.85	1.75	1.72	1.70	4.24
17. Prices on weekly specials	2.76	2.66	2.47	2.67	11.72
18. Availability of advertised items	2.54	2.50	2.14	2.27	8.22
19. Accuracy of checkout clerks	1.97	1.98	1.89	1.88	−1.00
20. Clarity of price markings	2.85	2.86	2.33	2.55	8.90
21. Your ability to choose between stores	2.08	2.13	1.82	1.97	5.84
22. Information available for comparing stores	2.91	2.82	2.54	2.78	12.53
Average (Var. 1, 5, 9–22)	2.50	2.47	2.18	2.29	6.18

sometimes. Only 10% indicated they rarely or never needed additional information. Young and better-educated consumers were significantly less satisfied with the information available for making store comparisons.

The student's t statistic was used to test the hypothesis that the increase in consumer satisfaction in the test market was significantly greater than the increase in consumer satisfaction in the control market. The specific test involved sixteen variables concerning food stores and their characteristics (1, 5, and 9–22 in table 5). The change in attitude among Ottawa-Hull respondents concerning store characteristics was significantly different than the change in attitude among Winnipeg consumers. Whereas Winnipeg respondents generally became more dissatisfied between the pretest and post-test, Ottawa-Hull respondents either increased in satisfaction or their dissatisfaction increased less than their Winnipeg counterparts.

The last column in table 5 indicates that for fifteen of the sixteen characteristics, Ottawa consumers increased their satisfaction relative to Winnipeg consumers from pretest to post-test. The relative increases in satisfaction were greatest for the "information available for comparing stores" and for "prices on weekly specials." This was expected. The relative increase in Ottawa consumers' satisfaction with their "ability to choose between stores" was less than expected.

The comparative price information program appears to have generally enhanced consumer satisfaction with food stores and their characteristics, even when the characteristics were unrelated to price information. (It is doubtful, for example, that the comparative price information program had an effect on store layout or parking space, yet Ottawa consumers indicated a relative increase in satisfaction with these factors over the study period.) This so-called "halo effect" has been found in other attitudinal studies and complicates the interpretation of results.

Consumers in both the test and control markets were asked in the post-test mail survey if they had recently changed stores. Approximately 43% of the Ottawa-Hull respondents

indicated they had temporarily or permanently changed stores compared to 18% of the Winnipeg respondents.

Consumer patronage in the Ottawa-Hull market shifted to retail stores with lower price index levels—suggesting that preinformation differences in prices did not reflect accurately consumer valuation of the differences in product-service offerings.[2] This led to an increase in the share of market held by the top four corporate chains from 74% to 81%. By comparison, the major store types in Winnipeg maintained relatively constant market shares.

Perceived Value of Information Program

Consumers in the test market were asked to indicate the maximum value they would be willing to pay to receive the comparative price information on a weekly basis. The mean value was 34.14¢ per week. There was no significant difference in the willingness to pay by that half of the sample who received the price comparison information by direct mail (as well as through newspapers) and the half who received the information through newspapers only.

Consumers in the test market were asked several specific questions about the experimental information program. When asked if the information program saved them time, 87% of the respondents replied "yes" or "sometimes." Similarly, 94% of the respondents indicated that the information program made them more aware of price differences between stores and between products. When asked to describe what they thought of the information program, the majority of consumers indicated that the program either (*a*) made them more aware, (*b*) reduced price levels, (*c*) increased competition, or (*d*) some combination thereof.

[2] When asked, "At what store do you buy most of your food?" test market consumers responded as follows during the pretest and post-test periods.

	Pretest	Post-test
A&P	1	1
Dominion	20	25
IGA	17	15
Loblaws	25	23
Steinbergs	27	32
A.L. Raymond	8	3.5
Others	2	0.5

Measures of Consumer Benefit

The information on food price comparisons provided by the study was a short-term "public good." Its value was not determined by the traditional market forces of supply and demand. Consequently, consumers' perceived value of the information served as a proxy in the absence of a market estimate.

Consumers indicated they would, on average, be willing to pay 34.14¢ per week or $1.36 per month for the price comparison information. With 118,000 families in the Ottawa-Hull market, the potential support for such a program would be about $174,541 a month and $2,094,500 annually. Although we expect these to be inflated estimates due to response bias, they provide a "ball park" estimate of the perceived value of the information program. The cost of the program, including consumer questionnaires, was approximately $3,500 per month.

The benefits of the comparative price program also can be estimated by computing the change in consumer surplus. With total monthly expenditures on food in the test market of $17,700,000, and assuming an aggregate demand elasticity of −0.2, a 5% drop in prices would result in an estimated gain in consumer surplus of $892,525.00 and a loss to retailers of $883,691.00. The resulting net benefit to society is $8,834.00 per month, assuming no changes in firm costs. If the price decline was associated at least in part with cost reductions, the net benefit to society would be correspondingly larger. It is of interest to note that if a permanent drop in price of 1% is assumed, the estimated gain in consumer surplus is $178,505 per month. This compares to $174,541 per month that consumers indicated they would be willing to pay for price comparison information.

Economic Implications

The results of this study indicate that the performance of markets can be affected significantly by the distribution of accurate and credible market information. Statistical analyses confirmed the major study hypotheses. (*a*) Significantly different prices for a standardized market basket of food products would be charged by competing sellers prior to the dissemination of comparative price information. (*b*) The public dissemination of comparative

price information would alter the dispersion of prices between stores and lower the average price level in the market. (*c*) Consumers in the test market who received information on comparative price offerings would show a significant increase in the level of satisfaction with market performance compared to consumers in the control group. (*d*) The perceived and estimated value of comparative price information would exceed the cost of providing such information.

Although the short period during which information was published precludes an assessment of the long-run results of such a program, in the short run, both pricing efficiency and consumer satisfaction were enhanced. In highly concentrated markets, the long-run consequences of a price information program might not be as laudable. The program might be used as an instrument for price collusion. If prices were monitored simultaneously in several markets, some of which were effectively competitive, collusive behavior might be detectable, however. The long-run effects of both continuous and intermittent information programs are currently being examined by the authors (Devine, 1978).

Market information is itself a dimension of market structure; however, it also influences other market structure dimensions. Estimated four-firm concentration in the test market increased from 74% to 81% between the pretest and post-test surveys. Because lower priced chains increased their market shares at the expense of higher priced firms, this shift appears to have resulted from the information program. Although the information program also was expected to reduce entry barriers, no measure of this structural dimension was attempted. In the long run, the structural change potential of market information may be more important than the immediate changes in market conduct and performance.

Consumers in the market derived benefit from the public dissemination of information whether they used the information or not. The fact that they could have used the information was enough of an impetus to generate a general price decline from which all consumers benefited. Additional benefits were realized by consumers who used the information to select lower priced stores. Forty-three percent of the test market respondents indicated that they changed stores as a result of the information program. This suggests that a significant proportion of consumers captured both the primary and secondary benefits of the additional information.

The results of this research indicate that public dissemination of retail price information deserves serious consideration. In addition to the effects indicated above, additional factors to be considered include:

(*a*) Comparative price information is essentially a public good.

(*b*) An inherent free rider problem is likely to prevent the private provision of comparative price information on a sufficient scale to police markets. Consumers quickly recognize that as long as "other" consumers search, the fruits of search activity can be enjoyed without the labor.

(*c*) Markets cannot be responsive to consumer preferences without some minimum level of consumer knowledge. Although the minimum is as yet undefined, existing levels of information in many consumer markets are thought to be inadequate. The response of consumers and retailers to increased information in this study indicates that pretest information levels were not sufficient to provide a stable informed equilibrium.

(*d*) Markets for consumer goods are becoming increasingly complex, making the search and evaluation process more difficult.

(*e*) Market price information is widely accepted in many commodity markets (both spot and futures), the stock exchanges, money markets, etc. In some of these, public agencies are responsible for gathering and reporting information; in others, private agencies do the job. Newspapers report much of this information free because of reader interest.

Consumers obviously choose their food stores on the basis of price and nonprice factors. Price comparison programs generally ignore differences in nonprice factors and leave it to consumers to evaluate such factors as store location, customer services, meat and produce quality, and store environment. Because nonprice factors are difficult to measure and are valued differently by different consumers, programs to provide comparative information on nonprice factors would appear to hold less potential for social benefits than a price comparison program.

Some may argue that developing price information programs is public invasion of business establishments. However, we contend that public comparison of privately publicized prices is a legitimate function of the public sector. Although privately produced, prices

are publicly displayed on counters, shelves, and in media advertisements every day of the week. Retail prices are therefore neither confidential nor private information. Only if price information is adequate and is shared among participants can we expect markets to perform efficiently.

[Received April 1978; revision accepted October 1978.]

References

Diamond, Peter. "A Model of Price Adjustment." *J. Econ. Theory,* 3(1971):156–68.

Devine, D. G. "An Examination of the Effects of Publishing Comparative Price Information on Price Dispersion and Consumer Satisfaction." Ph.D. thesis, Ohio State University, 1976.

———. "A Review of the Experimental Effects of Increased Price Information on the Performance of Canadian Retail Food Stores in the 1970's." *Can. J. Agr. Econ.* 26(1978):24–30.

Henderson, Dennis R. "Toward a Theory of Vertical Market Behavior." Dep. Agr. Econ. and Rural Soc. ESS 522, Ohio State University, June 1975.

Marion, B. W., and Charles H. Handy. "Market Performance: Concepts and Measures." USDA Agr. Econ. Rep. No. 244, 1973.

Nelson, Paul E. "Price Competition Among Retail Food Stores—Theory, Practice, and Policy Cues." *J. Farm Econ.* 48(1966):172–87.

Rothschild, Michael. "Models of Market Organization with Imperfect Information: A Survey." *J. Polit. Econ.* 81(1973):1283–1308.

Salop, Steve. "Information and Monopolistic Competition." *Amer. Econ. Rev.* 66(May 1976):240–45.

Stigler, G. D. "The Economics of Information." *J. Polit. Econ.* 69(1961):13–26.

The Impact on the Canadian Rapeseed Industry from Changes in Transport and Tariff Rates

W. H. Furtan, J. G. Nagy, and G. G. Storey

The economic viability and potential development of the Canadian rapeseed processing industry has been affected by a statute which allows raw rapeseed to be placed in export position at a rate two and one-half to three times lower than the processed oil and meal products and by a high Japanese rapeseed oil tariff. An analysis was undertaken to evaluate the effects on prices and trade flows of rapeseed, rapeseed oil, and rapeseed meal from policy changes in the Japanese rapeseed oil tariff and in Canadian freight rate policies. A four-region, three-commodity, spatial-equilibrium, quadratic-programming model of the world rapeseed industry was constructed to measure the impact of the various policy changes.

Key words: Canada, policy analysis, processing, quadratic programming, rapeseed, tariff, transportation.

The economic development of Western Canada, in particular the prairie provinces, has been constrained by high tariffs on processed food products and by a transport rate that encourages the shipment of raw agricultural commodities rather than processed agricultural products. The transportation cost (i.e., railway costs) of grain comes under the Crows Nest Pass Agreement. The agreement, which was signed in 1897 between the Dominion of Canada and the Canadian Pacific Railroad and is still in effect today, froze the transport rates of grain from Prairie points to export position in perpetuity.[1]

The Canadian rapeseed-crushing industry is an example of an industry which has not developed to its full economic potential because of the Crow rate and the existence of high tariff barriers against processed rapeseed products. Because rapeseed moves at the Crow rate and rapeseed oil faces a tariff barrier entering Japan, the Japanese crushers are able to pay a higher price for rapeseed than the Canadian crushers.[2] Consequently, Japan has a captive rapeseed supply.

Western rapeseed producers have been in favor of maintaining the existing Crow rate because they believe an increase in the freight cost could result in a direct and equal reduction in farm level grain prices. The validity of this premise depends upon the market power of the Canadian grain producer. Because Canada is the largest single exporter of rapeseed, there is reason to expect that a fraction of the subsidy paid on the cost of transporting the rapeseed is a direct subsidy to the foreign consumer of rapeseed and rapeseed products.

To date, there has been little empirical work on the economic impact that a change in the Crow rate or Japanese oil tariff would have on

---

W. Hartley Furtan is associate professor, Joseph G. Nagy is professional research associate, and Gary G. Storey is professor, University of Saskatchewan, Saskatoon.

The authors are grateful for financial support from the College of Agriculture, University of Saskatchewan. A special acknowledgment is extended to T. Gordon MacAulay, Agriculture Canada, for guidance and assistance with the methodological and operational aspects of the study.

[1] The agreement stated that the Canadian Pacific Railroad Company (CPR) would receive a subsidy for the building of a section of rail line through the Crows Nest Pass in the Rocky Mountains into the interior of British Columbia. In return, the CPR would (*a*) lower the rates on wheat and flour shipped from the Prairies to Fort William and Port Arthur (Thunder Bay) and maintain these rates "in perpetuity" and (*b*) reduce rates and tolls on settlers' effects transported from eastern to western Canada. Subsequent changes terminated the settlers' effects clause, applied the agreement to all rail lines and rail companies, and added oilseeds.

[2] An amendment to the Crows Nest Pass Agreement in 1961 allowed rapeseed to move at the statutory Crow rate but maintained compensatory rates on rapeseed oil and meal. Compensatory rates under the Canadian Railway Act are "deemed to be compensatory when it (the rates) exceeds the variable cost of the movement of the traffic concerned."

the Canadian rapeseed industry. Two commissions by the Canadian government have addressed themselves recently to the issue of freight costs and the Crows Nest Pact Agreement.[3] The Hall Commission has recommended that "freight rates on rapeseed and its derivatives be set at levels which do not discriminate against the natural locational advantage of Prairie rapeseed crushers" (p. 290). The Snavely Commission found that in 1974, "the costs incurred by the railways and the Federal Government combined were 2.61 times the charges paid by the user of the service" (p. 205).

This paper examines the effects on prices and trade flows of rapeseed, rapeseed oil, and rapeseed meal from changes in the Japanese rapeseed oil tariff and the Crow freight rate with reference to the Hall and Snavely Commissions. The analysis takes the form of modeling a four-region, three-commodity, spatial-equilibrium, quadratic-programming model of the world rapeseed industry for the year 1974. Five policy simulations are conducted: (*a*) an increase in the land freight on Canadian rapeseed transport by a factor of 2.61; (*b*) lowering the transport cost of Canadian rapeseed oil and meal to the Crow rate equivalent of seed; (*c*) removal of the Japanese rapeseed oil tariff; (*d*) a combination of policies *a* and *c*; and (*e*) a combination of policies *b* and *d*.

Theoretical Considerations

The equilibrium market conditions in a single commodity, multiregion case are usually expressed in terms of excess supply and demand curves (Shei and Thompson). The equilibrium price in each market is determined by the difference in transport and tariff charges. The quantities traded, produced, and consumed in each market relate to the price through the specified demand and supply curves.

In the general case of joint production, prices of the commodities are linked through a marketing margin equation. The objective function is then to maximize the net social payoff as calculated in all commodity markets. If a margin equation is employed, then this equation forms a derived demand in the primary commodity market. As shown in figure 1, once the supply of the primary product is known, then the supply of final products can be determined in each market. The objective function will then allocate the final product between the regions given the respective demand curves.

In figure 1, Market A represents the primary product market, while Market B represents intermediate product (there could also be other final product markets; however, for simplicity these markets are not included in the diagram). In Market A, country 1 has the excess supply, while country 2 has the excess demand. Given the demand for transportation services of the primary product (*DTSP*) and the unit transport costs (*TCP*), the quantity traded and consumed in each market and the price is determined. Once the quantity demanded of the primary product is determined in Market A, the supply curves of the intermediate product in Market B are determined for countries 1 and 2. Trade may also occur in Market B because of the differential freight costs between the two commodities, in tariffs between the commodities, or differences in the transformation rates of processing the primary commodity into the intermediate

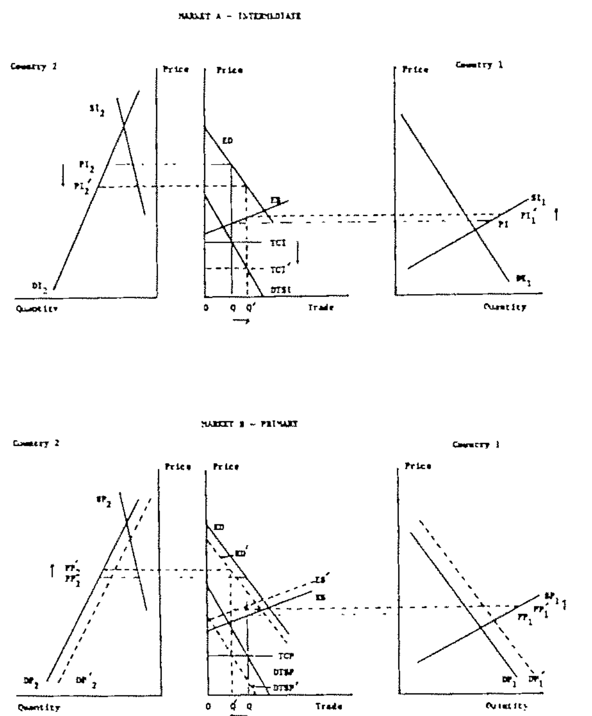


Figure 1. Excess demand and supply in primary and intermediate markets

[3] The two federal commissions were The Snavely Royal Commission on *The Costs of Transporting Grain by Rail* and *The Report of the Grain Handling and Transportation Commission* under Chief Commissioner Hon. Emmith M. Hall, Q.C.

product between the two countries. As shown in figure 1, trade takes place in both commodities, primary and intermediate.

Assume that the transfer cost of the intermediate product is reduced from *TCI* to *TCI'* in Market B. This, for example, could occur through a reduction in freight cost or a reduction in import tariff. This results in a lower price in the importing country and a higher price in the exporting country. This price change in the intermediate commodity market will shift the derived demand curves in the primary commodity markets because it affects the profitability of primary product processing (the derived demand curves in country 1 and 2 shift to the right). The excess supply and demand curves also shift, resulting in a new demand for transportation (*DTSP'*). The direction of change in primary product price will depend upon the relative elasticities of demand and supply in both Market A and Market B. However, the price spread in Market A between the two countries will remain the same.

The model presented in figure 1 suggests that country 1 will process more of the primary product, export less primary product, and expand its exports of the intermediate product to country 2 following from the reduction in transfer costs of the intermediate product. The extent to which this occurs depends upon the transfer cost differential between the intermediate commodities and the primary product, and the relative processing efficiencies in the two countries, plus the relevant demand and supply elasticities.

When building an empirical model of an economic situation described above, it is paramount that product flows be allowed to occur for all commodities. The quadratic programming model used in this study allowed for the flow of both the primary and intermediate products. In this way, the impact of changing the tariff and/or transport costs on one commodity (primary or intermediate) will have an appropriate impact on the remaining commodities.

The objective function of the model is the maximization of consumer plus producer surplus in the Canadian and Japanese rapeseed oil and meal markets, the European Economic Community (EEC) import demand for rapeseed market, and the Canadian rapeseed stock demand market. Because the supply of rapeseed is fixed, the total revenue for the products can be considered as producer surplus (Elliot). While some may argue that only the Canadian welfare function should be maximized in such a policy problem, the implications of such an analysis are not well understood in theory.

Mathematically, the model can be expressed as:

$$(1)\quad \text{Max } \theta = \sum_{i=1}^{2}\sum_{j=1}^{2} \int (a_{ij} + b_{ij}P_j)dP_j + \int (c + dP)dP + \int (e + fP)dP - \mathbf{T}'\mathbf{Q},$$

$$(2)\quad \text{s.t. } Q_{ij} = \gamma_{ij}Q_i^s,$$

for $i = 1, 2$ and $j = 1, 2$, and

$$(3)\quad P_{it}^s = W_{it} + \gamma_{i1}P_{it}^o + \gamma_{i2}P_{it}^m,$$

plus the usual market equilibrium condition given by Takayama and Judge. In this formulation, $i = 1, 2$ for Canada and Japan while $j = 1, 2$ for rapeseed oil and meal. The first integral is the demand equation for rapeseed oil and meal in Canada and Japan, the second integral is the EEC import demand for seed, and the third integral is for the Canadian rapeseed stocks demand. $\mathbf{T}$ is a vector of unit transport and tariff charges, while $\mathbf{Q}$ is a vector of the quantities shipped between markets of the specific commodities. The production of oil and meal is determined by the quantity crushed (Q_i^s) in each market. Finally, a margin equation is used to maintain the price relationship and form the derived demand for seed in the Canadian and Japanese markets as shown in equation 3 (where γ_{ij} is the conversion rate for oil and meal and P^s is the price of rapeseed, P^o the price of oil, and P^m the price of meal). These equations are represented in quadratic programming matrix form in a subsequent section of the paper.

The margin equations for Canada and Japan are price-dependent, derived demand equations. The reason for this specification is (*a*) price data are more readily available, and (*b*) the prices of the rapeseed products, more closely related to the soybean market than to the quantity of rapeseed products moved through the market. A further discussion and justification of price-dependent, derived demand equations is given by Heien.

Market Specification of the Model

The four regions included in the model are Canada, Japan, the EEC, and a region encom-

passing the rest of the world (ROW). The model facilitates trade flows of seed, oil, and meal and spatially links the commodities in each region by transport and tariff charges. The model also allows Canada to crush rapeseed into oil and meal for its domestic market and export oil and meal to the other three regions.

The trade flow linkages in the model allow Canada as a region to export its rapeseed production to the other three regions. In 1974, 90% of Canadian rapeseed exports were exported to Japan. The EEC and ROW imported the remainder, with the EEC importing the larger share. Between 90%–95% of Canadian production of both oil and meal were domestically consumed, with the remainder exported. Trade between Canada and countries in the ROW region was mainly facilitated through government grants and aid programs.

Japan has an oil import tariff of 17,000 yen/tonne ($57.02 Canadian in 1974) which effectively prevented Canadian entrance into the Japanese rapeseed oil market. Because oil and meal are joint products, the Japanese tariff on the higher valued oil product effectually blocks Canada's entry to the protein meal market. The EEC has a 10% ad valorem tariff on rapeseed oil imports, but has no tariff on meal.

Japan is a deficit area for rapeseed and rapeseed products. Rapeseed production in Japan has fallen from 263.6 thousand tonnes in 1960 to 6.2 thousand tonnes in 1975. The reasons for the decline are apparently pressures on the land by urbanization and competing crops as well as competition for labor. Japan imports and crushes rapeseed to satisfy a strong rapeseed oil and meal demand. Depending upon the year, between 80%–100% of Japanese rapeseed imports are supplied by Canada. Japan imports small amounts of rapeseed oil and meal from other regions.

In the model, the EEC is treated as a net import region for Canadian rapeseed, oil, and meal and an exogenous supplier of rapeseed, oil, and meal to Japan. The EEC is basically a deficit area for rapeseed, although it does export all three commodities. This can be explained. The EEC is made up of nine member countries some of which import, and others export, outside the EEC boundaries. Also, EEC rapeseed and, hence, rapeseed products are of different quality from that of Canada.

The ROW region in the model is treated as an exogenous supplier of rapeseed, oil, and meal to both Japan and the EEC and an exogenous importer from Canada and the EEC. For purposes of policy analysis, the limited quantities involved make it reasonable to assume that imports by Japan from the EEC and ROW are fixed.

Consequently, the regions most important to the examination of the impact of a change in transportaton and traffic changes on the Canadian rapeseed industry are Japan and Canada and, to a lesser extent, the EEC.

The Empirical Model

The following sections outline the specification for the supply, demand, and spatial characteristics of the model.

The Supply of Seed, Oil, and Meal

The supply of Canadian rapeseed available in 1974 for the domestic market, Japan, and the EEC, when adjusted for shipments to the ROW region, was 1,688.9 thousand tonnes. The supply of Japanese rapeseed available for the Japanese domestic market in 1974 was 9.3 thousand tonnes. The exogenous supply of rapeseed that entered the Japanese market from the EEC and ROW in 1974 was 192.5 thousand tonnes. The rapeseed supplies, as indicated above, were entered into the model as perfectly inelastic.

Rapeseed oil and meal are joint products and thus are produced in fixed proportions. The exact proportion of oil and meal from a unit of crushed rapeseed depends upon the efficiency of the crushing plants and the quality of the seed. In 1974, Canadian crushers extracted 410 kilograms of oil and 570 kilograms of meal from one tonne of seed. The Japanese extraction rates in 1974 were 391 kilograms of oil and 581 kilograms of meal from one tonne of rapeseed. Given that oil and meal are extracted in fixed proportions, the supply of oil and meal available to the market is fixed once the annual rapeseed crush has been determined.

Rapeseed Oil and Meal Demand

Rapeseed is primarily used as an edible oil in the manufacturing of margarines, shortenings, and salad oils. Rapeseed meal is used as a protein supplement in livestock feeds and also as fertilizer in Japan. The rapeseed oil and

meal demand equations for 1974 are presented in table 1. The Canadian and Japanese oil and meal equations are total disappearance demand equations. The EEC oil and meal equations are total import demand equations adjusted for Canadian market shares. That is, a total import demand equation is first estimated and then adjusted for Canadian market share by multiplying the estimated equation through by the percentage imported from Canada. The imports of oil and meal by the ROW region from Canada are fixed and assumed nonprice responsive at their 1974 levels of 23.70 and 12.63 tonnes, respectively.

To solve a spatial equilibrium problem, the objective function must be evaluated in a common currency. The approach suggested by Elliot, and empirically used by MacAulay, was employed. The approach involves estimating all the demand equations in their respective national currencies and then converting to a common currency (in this case Canadian) by multiplying the price coefficients by the actual exchange rate for the period in question.

The Demand for Seed

The EEC seed demand equation presented in table 1 is the total EEC import demand adjusted for Canadian market share. Because the level of Canadian stocks of rapeseed is a significant quantity in relation to the quantity crushed, a stocks demand equation was estimated. Japan's rapeseed stock holdings are insignificant and, therefore, were not estimated. The imports of rapeseed from Canada by the ROW region are assumed to be nonprice responsive and were fixed at the 1974 level of 124.0 thousand tonnes.

The model allows Canada and Japan to transform rapeseed into oil and meal. Thus, the demand for seed is derived demand that develops because crushers want to buy seed and crush the seed in response to a demand for rapeseed oil and meal. The price the crusher will pay for seed depends on the crusher's expected or realized price for oil and meal, the cost of processing, and the crusher's required profit margin. This relationship is expressed in equation (4) as

$$(4) \qquad P_t^s = \gamma_1 \, (P_t^o) + \gamma_2 \, (P_t^m) + W_t,$$

where P_t^s is the price of seed; P_t^o, the price of oil; P_t^m, the price of meal; W_t, the crushing and handling margin; γ_1, the percentage yield of oil per unit of crushed seed; and γ_2, the percentage yield of meal per unit of crushed seed.

Equation (4) is the price linkage between the primary product rapeseed and final products oil and meal. For the purpose of the model, the crushing and handling margin (W_t) is calculated as a residual for 1974 for both Canada and Japan, and fixed at that rate for the policy simulations, thus allowing the model to determine P_t^o, P_t^m, and P_t^s, given the demand for oil and meal and a perfectly inelastic supply of seed. Thus, the price linkage equation replaces the traditional two-dimensional demand equation for seed in the Canadian and Japanese markets.[4]

[4] The 1974 crushing margin equations for Canada (W_1) and Japan (W_2) are as follows:

$$(1) \quad W_1 = 0.41\,(774.48) + 0.57\,(109.23) - 312.51 = \$67.29/\text{tonne, and}$$

Table 1. Estimates of Regional Demand Equations, 1974

	Intercept	Price Coefficient	Elasticity	$\bar{R}^2$	Durbin-Watson Statistic	Thiel's Forecasting Coefficient
Rapeseed oil demand						
Canada	266.14	−0.236	−3.78	0.72	2.07	0.110
Japan	789.90	−0.632	−1.17	0.79	2.03	0.086
EEC	9.24	−0.010	−4.08	0.79	1.37	0.190
Rapeseed meal demand						
Canada	253.27	−0.918	−0.63	0.82	0.94	0.090
Japan	529.15	−1.014	−0.58	0.96	2.40	0.067
EEC	60.77	−0.290	−1.86	0.80	1.49	0.146
Rapeseed demand						
Canada (Stocks)	1027.73	−0.530	−0.10	0.98	1.30	0.049
EEC	92.63	−0.160	−0.65	0.50	1.28	0.300

Note: All equations are linear and estimated using OLS. All price coefficients are significant at the 5% level with the exception of the EEC rapeseed demand equation which is significant at the 10% level.

Transport and Tariff Cost

Canada, Japan, and the EEC are spatially separated and linked by transport and tariff costs in the model. Table 2 presents the transport and tariff charges that existed in 1974 for the shipment of seed, oil, and meal from Canada to Japan through the port of Vancouver and from Canada to the EEC through Thunder Bay and Eastern ports. The land freight charges in Canada on rapeseed are the statutory Crow freight rate and the oil and meal charges are the compensatory freight rates.

Table 2. Rapeseed Seed, Oil, and Meal Transport and Tariff Rates, 1974

Destination of Product	Land Freight	Total Transport Cost	Tariff	Total Transport and Tariff Cost
		($/tonne)		
Saskatoon—Japan				
Seed	5.17	60.30	0.0	60.30
Oil	24.25	84.24	57.02	141.26
Meal	13.67	75.00	0.0	75.00
Saskatoon—Rotterdam				
Seed	5.17	48.88	0.0	48.00
Oil	24.25	72.05	a	72.05
Meal	5.18	54.88	0.0	54.88

Source: Seed transport costs are taken from Canada, Grains Council *Handbook*. Oil and meal transport and tariff rates were supplied by CSP Foods Ltd., Saskatoon, Saskatchewan.
[a] 10% ad valorem tariff.

The Quadratic Programming Matrix and Model Validation

The linking of the three different commodities—rapeseed, oil, and meal—among the four regions is presented by the quadratic programming matrix in table 3. (The notation of the matrix is given in table 4.) All the collapsed two-dimensional demand functions for oil, meal, and seed along with the predetermined seed supply and transport and tariff charges are brought together to form the basic structure of the model.

The model was validated for 1974 by setting all exogenous seed supplies, gross crushing margins, and transportation and tariffs to 1974 levels. The model was solved in net revenue form (Takayama and Judge). The actual 1974 levels with those of the solution prices and trade flows are given in table 5. The solution results of the model are reasonably close to the actual 1974 figures. The model fairly accurately represents the price-quantity and spatial relationships for oil, meal, and seed between regions.

(2) $W_2 = .391\ (837.61) + 0.581\ (151.61) - 348.30 = \$67.29/\text{tonne}.$

A problem existed in obtaining a reliable Japanese seed price for the 1974 calendar year that was consistent with the oil and meal prices. Initially, equation (2) presented the problem of having two unknowns, P_i^s and W_{2i}. However, it was possible to establish from consultations with people in the industry that the Japanese crushing margin in 1974 was very similar to the Canadian crushing margin.

The Empirical Results

Five policy simulations were conducted. They involved specified changes in the Crow freight rate and the removal of the Japanese rapeseed oil tariff. The results of the five policy simulations were compared against the validation results in table 5. Table 6 presents the changes in prices and trade flows from the five policy simulations.

Simulation I: Removal of the Statutory Crow Rate

When the costs of transporting Canadian rapeseed to export position increases to the level of the compensatory rate (2.61 × the statutory Crow freight rate as found by Snavely, or $8.32/tonne), a new market equilibrium results (see table 6, column 1).

The Japanese and EEC crushers are less competitive than the Canadian crushers; thus Canada increases its crush by 13.26 thousand tonnes while Japan decreases its crush by 14.34 thousand tonnes. The price of rapeseed falls in Canada by $3.50 per tonne and increases in Japan and the EEC by $4.82 per tonne. Canadian access to the Japanese oil market improves slightly with an increase of rapeseed oil exports of 5.46 thousand tonnes. Rapeseed oil prices increase slightly in all three markets and meal prices decrease in Canada and the EEC and increase in Japan.

The Canadian rapeseed producers do not bear the total burden of the 8.32 per tonne increase in transport cost. The burden is shared: Canadian rapeseed producers lose $3.50 per tonne and the remaining $4.82 per tonne is passed on to the consumer of rapeseed products in Japan and the EEC. The Japanese crusher is able to bid $4.82 per tonne more for rapeseed and meal in terms of higher prices. The Japanese crusher is able to pass

Table 3. The 1974 Rapeseed Quadratic Programming Matrix

ROWS \ COLUMNS	DPM1	DPM2	DPM3	DPM4	SPM1	SPM2	DPO1	DPO2	DPO3	DPO4	SPO1	SPO2	DPS3	DSS1	SPS1	SPS2	XM11	XM12	XM13	XM14	XM22	XO11	XO12	XO13	XO14	XO22	XS11	XS12	XS13	XX11	XS22	R.H.S.
	DEMAND AND SUPPLY PRICE COLUMNS																QUANTITY TRANSFER COLUMNS															
	Meal						Oil						Seed				Meal					Oil					Seed					
DPM1	.92																1															
DPM2		1.01																1			1											
DPM3			.29																1													
DPM4				—																1												
SPM1					—												-1	-1	-1	-1								.57					
SPM2						—															-1								.581			.581	
DPO1							.24															1										
DPO2								.63															1			1						
DPO3									.01															1								
DPO4										—															1							
SPO1											—											-1	-1	-1	-1		.41					
SPO2												—														-1		.391			.391	
DPS3													.16																1			
CSS1														.53																1		
SPS1															—												-1	-1	-1	-1		
SPS2																—															-1	
XM11	-1				1																											
XM12		-1			1																											
XM13			-1		1																											
XM14				-1	1																											
XM22		-1				1																										
XO11							-1				1																					
XO12								-1			1																					
XO13									-.91		1																					
XO14										-1	1																					
XO22								-1				1																				
XS11					-.57						-.41				1																	
XS12						-.581						-.391			1																	
XS13													-1		1																	
XX11														-1	1																	
XS22						-.581						-.391				1																
LINEAR OBJECTIVE FUNCTION	-253.27	-529.15	-60.77	-12.63	0.0	0.0	-266.14	-787.90	-9.24	-23.70	0.0	0.0	-92.63	-1027.73	1689.00	201.80	0.0	75.00	54.88	0.0	0.0	0.0	141.26	72.05	0.0	0.0	67.29	127.59	48.88	0.0	67.29	
RDPM1	-.92																-1															≤ -253.27
RDPM2		-1.01																-1			-1											≤ -529.15
RDPM3			-.29																-1													≤ -60.77
RDPM4				—																-1												≤ -12.63
RSPM1					—												1	1	1	1								-.57					≤ 0.0
RSPM2						—															1								-.581			-.581	≤ 0.0
RDPO1							-.24															-1										≤ -266.14
RDPO2								-.63															-1			-1						≤ -787.90
RDPO3									-.01															1								≤ -9.24
RDPO4										—															-1							≤ -23.70
RSPO1											—											1	1	1	1		-.41					≤ 0.0
RSPO2												—														1		-.391			-.391	≤ 0.0
RDPS3													-.16																-1			≤ -92.63
RCSS1														-.53																-1		≤ -1027.73
RSPS1															—												1	1	1	1		≤ 1689.00
RSPS2																—															1	≤ 201.80
RXM11	1				-1																											≤ 0.0
RXM12		1			-1																											≤ 75.00
RXM13			1		-1																											≤ 54.88
RXM14				1	-1																											≤ 0.0
RXM22		1				-1																										≤ 0.0
RXO11							1				-1																					≤ 0.0
RXO12								1			-1																					≤ 141.26
RXO13									.91		-1																					≤ 72.05
RXO14										1	-1																					≤ 0.0
RXO22								1				-1																				≤ 0.0
RXS11					.57						.41				-1																	≤ 67.29
RXS12						.581						.391			-1																	≤ 127.59
RXS13													1		-1																	≤ 48.88
RXX11														1	-1																	≤ 0.0
RXS22						.581						.391				-1																≤ 67.29

part of this increased price on to the Japanese consumer of rapeseed oil because of the Japanese oil tariff. Consequently, the Crow rate subsidy is not only a subsidy to Canadian rapeseed producers but a subsidy to foreign consumers of rapeseed products as well.

Table 4. Quadratic Programming Matrix Notations

Rapeseed Meal Demand
- DPM1 = Canadian rapeseed meal demand
- DPM2 = Japanese rapeseed meal demand
- DPM3 = EEC rapeseed meal demand from Canada
- DPM4 = Rest of world rapeseed meal demand from Canada

Rapeseed Meal Supply
- SPM1 = Canadian supply of rapeseed meal
- SPM2 = Japanese supply of rapeseed meal

Rapeseed Oil Demand
- DPO1 = Canadian rapeseed oil demand
- DPO2 = Japanese rapeseed oil demand
- DPO3 = EEC rapeseed oil demand from Canada
- DPO4 = Rest of world rapeseed oil demand from Canada

Rapeseed Oil Supply
- SPO1 = Canadian supply of rapeseed oil
- SPO2 = Japanese supply of rapeseed oil

Seed Demand
- DPS3 = EEC import demand from Canada
- CSS1 = Canadian rapeseed stocks demand

Seed Supply
- SPS1 = Canadian opening stocks plus production less seed sold to countries other than Japan and the EEC
- SPS2 = Japanese production plus imports of seed from countries other than Canada

Rapeseed Meal Transfer
- XM11 = Canadian consumption of Canadian meal production
- XM12 = Japanese imports of Canadian meal
- XM13 = EEC imports of Canadian meal
- XM14 = Rest of world imports of Canadian meal
- XM22 = Japanese consumption of Japanese meal production

Rapeseed Oil Transfer
- XO11 = Canadian consumption of Canadian oil production
- XO12 = Japanese imports of Canadian oil
- XO13 = EEC imports of Canadian oil
- XO14 = Rest of world imports of Canadian oil
- XO22 = Japanese consumption of Japanese oil production

Rapeseed Seed Transfer
- XS11 = Proportion Canada crushed of Canadian seed supply
- XS12 = Japanese imports of Canadian seed
- XS13 = EEC imports of Canadian seed
- XX11 = Canadian stocks demand from Canadian seed supply
- XS22 = Proportion Japan crushed of Japanese seed supply

Note: The only difference between the notation of the rows of the quadratic objective function and the linear constraint set of the matrix is the addition of an *R*. However, they have the same meaning.

Simulation II: Oil and Meal on Statutory Crow Rate Equivalent

The alternative to increasing the statutory Crow freight rate and still be in keeping with the Hall Commission's recommendations is to lower the compensatory rate on rapeseed oil and meal to the Crow freight rate equivalent for seed. The effects of such a policy change are shown in table 6, column 2.

The decrease in the oil transport rate allows Canadian crushers a small increase in oil exports to Japan of 8.57 thousand tonnes. Canadian crushers are more competitive and bid up the price of rapeseed by $1.75 per tonne. Canada crushes 13.49 thousand tonnes more and Japan 12.29 thousand tonnes less. Meal prices rise in Japan, but decrease in both Canada and the EEC. Oil prices rise in Canada and decrease in both Japan and the EEC.

Such a policy would achieve the Hall Commission recommendations while improving the Canadian rapeseed producer's position, unlike the policy in Simulation I. Although not examined in this study, a policy of placing rapeseed oil and meal on the same level as Crow freight rate cost structure may enable Canadian crushers to enter markets such as North Africa, where there is a strong demand for rapeseed oil. However, the policy means more subsidization to the railroads which would have to be borne by the federal treasury.

Simulation III: Removal of the Japanese Rapeseed Oil Tariff

When the $57.02 per tonne Japanese oil tariff is removed while holding the land freight charge on rapeseed at the present statutory Crow rate charge, Canada gains access to the Japanese oil market.[5] Canadian crushers bid away Canadian rapeseed from the Japanese crushers and, thus, Canadian rapeseed producers receive a $4.97 per tonne increase for rapeseed. Japan imports 36.77 thousand tonnes less rapeseed from Canada and Canadian crushers crush 40.2 thousand tonnes more. Canada exports 26.03 thousand tonnes more rapeseed oil to Japan, but no meal is exported to Japan. As would be expected, oil prices rise in both Canada and the EEC and decrease in Japan, while meal prices rise in

[5] The simulations are run removing the Japanese tariff on rapeseed oil alone. The Japanese tariff on other oils such as soybeans remain intact. In order to analyze the simultaneous effect of removing the soybean and rapeseed oil tariff one could (*a*) build a model including the soybean market, or (*b*) change the own-price elasticity on the Japanese rapeseed oil demand. However, the current Japanese policy of importing vegetable oils is one where all oils do not face similar tariffs; thus, there is no a priori reason to believe that soybean oil and rapeseed oil tariffs need to be changed in a corresponding fashion. In fact, it is in the Canadian favor to argue for a change in rapeseed oil tariff and have the soybean oil tariff remain as is.

Table 5. Validation of Rapeseed Model for 1974

Prices and Transactions	1974 Actual Prices and Transactions	Validation	Deviation from Actual	Percentage Deviation from Actual
	Meal, Oil, and Seed Prices ($/tonne)			
Meal price				
Canada	109.23	111.64	+2.41	+2.2
Japan	151.61	142.65	−8.96	−5.9
EEC	156.26	166.52	+10.26	+6.5
Oil price				
Canada	774.48	694.68	−79.80	−10.3
Japan	837.61	835.94	−1.67	−0.1
EEC	775.05	842.56	+67.51	+8.7
Seed price				
Canada	312.51	281.17	−31.34	−9.0
Japan	348.30	341.47	−6.83	−1.9
EEC	336.40	330.05	−6.35	−1.9
	Meal, Oil, and Seed Transactions (thou. tonnes)			
Meal transactions				
Canadian consumption	148.30	150.78	+2.48	+1.7
Canadian exports to Japan	0.0	0.0	0.0	0.0
Canadian exports to EEC	18.38	12.64	−5.74	−31.2
Japanese production	396.00	384.50	−11.50	−2.9
Oil transactions				
Canadian consumption	82.60	102.20	+19.60	+23.7
Canadian exports to Japan	3.33	1.04	−2.29	−31.2
Canadian exports to EEC	1.24	0.81	−0.43	−34.7
Japanese production	267.00	258.54	−8.46	−3.2
Seed transactions				
Canadian crush	292.64	308.67	+16.03	+5.5
Canadian exports to Japan	486.15	461.13	−25.02	−5.1
Canadian exports to EEC	46.37	40.48	−5.89	−12.7
Japan's own and exogenous crush	201.80	201.80	0.0	0.0
Canadian seed stocks	955.80	878.72	−77.08	−8.1

Japan and decrease in both Canada and the EEC.

The results show that the Japanese tariff is effective in preventing Canadian rapeseed oil from entering Japan. However, even with the removal of the tariffs, Japan is still an effective competitor for Canadian rapeseed because of the Crow freight rate subsidy on rapeseed transportation.

Simulation IV: Removal of the Crow Rate and the Japanese Rapeseed Oil Tariff

A policy simulation was conducted where rapeseed was removed from the Crow rate (2.61 × the Crow rate) along with the removal of the Japanese oil tariff. The results as shown in table 6, column 4, indicate that if all barriers to trade on rapeseed and its products were removed between Canada and Japan, processing would take place near the source of rapeseed supply. Canada no longer exports rapeseed to Japan, but crushes rapeseed in Canada and exports 241 thousand tonnes more meal and 197.3 thousand tonnes more oil to Japan than in 1974.

The effect on the price of rapeseed from the combination of the two policies results in an increase of $1.45 per tonne. Thus, the removal of the Japanese oil tariffs has a positive impact on the Canadian rapeseed price and overrides the removal of the Crow freight rates negative effect on Canadian rapeseed price.

A sensitivity analysis was carried out to find the range at which the Japanese tariff was effective in shifting the location of crushing activity. It was found that to change the crushing location from Japan to Canada when seed is transported at 2.61 times the Crow rate, the Japanese oil tariff would have to be reduced between 70%–80%.

Simulation V: Oil and Meal on Crow and Removal of Japanese Rapeseed Oil Tariff

When the Japanese tariff is removed along with the placement of Canadian rapeseed oil and meal on the Crow freight rate level, there

Table 6. Changes in Solution of Prices and Trade Flows of Rapeseed Meal, Oil, and Seed

Prices and Transactions	Policy Simulations I	II	III	IV	V
	Changes in Meal, Oil, and Seed Prices ($/tonne)				
Meal price					
Canada	−6.25	−5.86	−18.96	−18.59	−15.57
Japan	+8.21	+7.03	+21.03	−25.40	+19.91
EEC	−6.25	−6.36	−18.96	−18.59	−15.57
Oil price					
Canada	+0.18	+13.10	+38.52	+29.39	+41.77
Japan	+0.82	−5.98	−18.50	−27.63	−34.33
EEC	+0.20	−6.57	+42.33	+32.30	+24.93
Seed price					
Canada	−3.50	+1.74	+4.97	+1.45	+8.24
Japan	+4.82	+1.74	+4.97	+3.95	−1.87
EEC	+4.82	+1.74	+4.97	+9.77	+8.24
	Changes in Meal, Oil, and Seed Transactions (thou. tonnes)				
Meal transactions					
Canadian consumption	+5.74	+5.84	+17.41	+17.07	+14.30
Canadian exports to Japan	0.0	0.0	0.0	+241.70	+247.26
Canadian exports to EEC	+1.81	+1.84	+5.49	+5.38	+4.51
Japanese production	−8.32	−7.13	−21.33	−267.46	−267.46
Oil transactions					
Canadian consumption	−0.05	−3.10	−9.10	−6.94	−9.86
Canadian exports to Japan	+5.46	+8.57	+26.03	+197.30	+201.54
Canadian exports to EEC	−0.01	+0.07	−0.43	−0.32	−0.24
Japanese production	−5.59	−4.79	−14.34	−179.84	−179.84
Seed transactions					
Canadian crush	+13.26	+13.49	+40.20	+463.45	+466.81
Canadian exports to Japan	−14.34	−12.29	−36.77	−461.13	−461.13
Canadian exports to EEC	−0.76	−0.27	−0.78	−1.55	−1.30
Canadian rapeseed stocks	+1.84	−0.94	−2.65	−0.78	−4.38

is a locational shift in crushing (table 6, column 5). As in simulation IV, Canada no longer exports rapeseed to Japan, but crushes it in Canada and exports increased quantities of oil and meal to Japan. Rapeseed producers receive a price increase of $8.24 per tonne. A sensitivity analysis indicated that to change the crushing location from Japan to Canada when oil and meal are on the Crow freight rate equivalent, the Japanese oil tariff would have to be reduced by 50%–60%.

Limitations and Conclusions

The assumption was made that the world rapeseed industry could be partitioned into four regions and the ROW region treated as an exogenous exporter and importer of rapeseed and rapeseed products. This assumption may be limiting in that, given a change in transportation costs of oil and meal, Canada may gain access to the strong North African oil markets.

The analysis in this study was for one year and the supply of rapeseed was fixed. Thus, the analysis ignores the long run effects of changing seed supply in response to changes in prices received by producers.

This analysis shows that the current prices and trade flows of rapeseed, rapeseed oil, and rapeseed meal are a function of Canadian and Japanese policy variables. A significant result of the study is the demonstration that the Crow rate subsidy on rapeseed transportation in Canada is not only a subsidy to the western Canadian rapeseed producer, but is also a subsidy to the foreign consumer of rapeseed products.

The Crow rate subsidy on rapeseed and the Japanese oil tariff make Canada a captive supplier of rapeseed for the Japanese crusher. This places Canadian rapeseed crushers at an economic disadvantage with respect to the ability to compete effectively with Japanese crushers for Canadian rapeseed as well as the Japanese oil and meal markets.

The results indicate that either a change in the Crow rate cost structure or the removal of the Japanese rapeseed oil tariff will increase

Canadian rapeseed processing. However, both would have to be removed before the major portion of Canadian rapeseed production was crushed at its source in Western Canada.

Finally, the development of this model indicates the usefulness of the quadratic programming model to problems where changes in spatial transfer costs effect not only commodities at one market level, but commodities at various market levels, from primary to final products.

[Received May 1978; revision accepted September 1978.]

References

Canada, Grains Council. *Canadian Grains Industry Statistical Handbook*. Winnipeg, 1977.

Elliot, D. "Converting National Supply and Demand Equations to a Common Currency for Internationally Traded Commodities." *Amer. J. Agr. Econ.* 54(1972):538.

Hall Commission. *The Report of the Grain Handling and Transportation Commission*. Ottawa: Government of Canada, 1977.

Heien, Dale. "An Econometric Model of the U.S. Pork Economy." *Rev. Econ. and Statist.* 57(1975):370–75.

MacAulay, T. G. "Forecasting Models of the United States and Canadian Pork Sector." *Canadian Commodity Food Models*. Ottawa: Agriculture Canada, forthcoming.

Shei, Shun-Yi, and Robert L. Thompson. "The Impact of Trade Restrictions on Price Stability in the World Wheat Market." *Amer. J. Agr. Econ.* 59(1977):628–38.

Snavely Commission. *The Costs of Transporting Grain by Rail*. Ottawa: Government of Canada, 1977.

Takayama, T., and G. G. Judge. *Spatial and Temporal Price and Allocation Models*. Amsterdam: North-Holland Publishing Co., 1971.

A Critique of Exchange Rate Treatment in Agricultural Trade Models

Robert G. Chambers and Richard E. Just

The recent theoretical and empirical literature on the role of exchange rates in agricultural prices and trade is reviewed. Specifically, alternative specifications of the exchange rate in excess demand functions are considered. Results show that the specification most common in recent theoretical and empirical work is unnecessarily restrictive and may bias the resulting analysis. Several less restrictive specifications for empirical research are suggested.

Key words: exchange rate, export demand, trade.

The early 1970s witnessed dramatic increases in farm as well as nonfarm prices. Because these increases followed a series of devaluations, a natural supposition is that the devaluations of the U.S. dollar had an important impact on farm and nonfarm prices. Several studies have attempted to measure the effects of the devaluations on farm prices and exports. Thus far, the results have been mixed. Schuh and Fletcher, Just, and Schmitz have suggested that the exchange rate devaluations have been an important determinant of agricultural exports and have led, in part, to the high domestic prices of the early 1970s. Vellianitis-Fidas, Kost, Greenshields, and Johnson, Grennes, and Thursby have found, on the other hand, that the exchange rate devaluation had relatively little impact on the agricultural sector of the economy. Thus far, it appears that the divergence in the results may be due to the alternative specification of export or excess demand and supply equations. To resolve this issue, a much closer look at the underlying theoretical issues is instructive.

The purpose of this paper is to review critically both the theoretical and empirical results in the recent agricultural economics literature on the effects of devaluation of the exchange rate on agricultural markets. The following section reviews the theoretical justifications that have been offered for various specifications. These arguments are then evaluated in the more general context of neoclassical demand and supply theory. Implications are drawn with respect to a number of the empirical studies on the role of exchange rates in agriculture. It becomes apparent that the most common specification in empirical work is overly restrictive, and no appropriate justification (empirical or otherwise) has been offered as yet for the associated conditions.

The Theoretical Framework of Devaluation in the Literature

The standard theoretical model used in the examination of the impact of devaluation on the market for an agricultural commodity can be expressed in terms of a simple two-country excess supply and excess demand model. For this purpose, let

$$\text{(1a)} \qquad D_i = f(\gamma_i) \qquad \partial f/\partial \gamma_i < 0,$$

$$\text{(1b)} \qquad S_i = g(p_i) \qquad \partial g/\partial p_i > 0, \text{ and}$$

$$\text{(1c)} \qquad D_i = S_i = Q_i,$$

where D_i is the excess demand for commodity i in the importing country taken to be a function of the market price γ_i in the importing country, S_i is the excess supply of commodity i in the exporting country taken to be a function of the market price p_i in the exporting country, and Q_i is the quantity of commodity i traded. It is assumed that in the absence of transportation costs and other barriers to trade

Robert G. Chambers is assistant professor of agricultural economics and rural sociology at the Ohio State University but, at the time of the research reported herein, was a postgraduate research agricultural economist at the University of California, Berkeley. Richard E. Just is an associate professor of agricultural and resource economics at the University of California, Berkeley.

Giannini Foundation Paper No. 505.

that, in equilibrium, the law of one price holds, i.e.,

$$(2) \qquad \gamma_i = p_i e,$$

where e is the exchange rate evaluated in terms of the units of the importer's currency per unit of the exporter's currency.

Kost and Bredahl and Womack use a linear variant of this model in an attempt to show that the percentage change of the price in terms of the exporter's currency due to a devaluation by the exporter may be less than the percentage of devaluation and in no case can exceed the percentage of devaluation.[1] To see the argument, differentiate the equilibrium condition to obtain

$$(3) \qquad \frac{dp_i}{de} = \frac{(\partial f/\partial \gamma_i)p_i}{(\partial g/\partial p_i) - (\partial f/\partial \gamma_i)e} < 0.$$

Equation (3) implies that a devaluation by the exporter leads to an increase in price in terms of the exporter's currency.[2] Using (3), the elasticity of the exporter's price with respect to the exchange rate, $\zeta_i = (dp_i/de) \cdot (e/p_i)$, can be written as

$$(4) \qquad \zeta_i = \frac{(\partial f/\partial \gamma_i)e}{(\partial g/\partial p_i) - (\partial f/\partial \gamma_i)e}.$$

Note that in equilibrium (4) can be rewritten as

$$(5) \qquad \zeta_i = \frac{-\eta_i}{\eta_i - \epsilon_i}$$

where ϵ_i is the elasticity of excess supply with respect to the price in terms of the exporter's currency (p_i), and η_i is the elasticity of excess demand with respect to p_i.[3] From (5), it should be clear that ζ_i is confined to the closed interval $[0, -1]$ since $\eta_i < 0$ and $\epsilon_i > 0$.

As an illustration of this result, consider figures 1 and 2. Figure 1 represents the case where the elasticity of excess supply with respect to price is zero. A devaluation would shift the excess demand curve from D^1 to D^2 (note that the shift is not a parallel shift but a percentage shift) so that exports remain constant, but equilibrium price in terms of the exporter's currency rises from p^1 to p^2; $(p^2 - p^1)/p^1$, the percentage change in price, is exactly equal to the percentage of devaluation. Figure 2 represents the case where excess supply is perfectly elastic and devaluation has no impact on prices; all adjustment comes in terms of an increase in exports.

To see, on the other hand, that the percentage change in exports due to a devaluation may be greater than the percentage change in prices, note first that excess supply is not directly responsive to changes in the exchange rate but that it is responsive to changes in price denominated in the exporter's currency. Following Bredahl and Womack, the exchange rate elasticity of exports of good i in equilibrium is

$$(6) \qquad \zeta_i = \frac{dQ_i}{de}\frac{e}{Q_i} = \frac{dp_i}{de}\frac{e}{p_i}\frac{dS_i}{dp_i}\frac{p_i}{S_i} = \zeta_i \epsilon_i,$$

since $Q_i = S_i = D_i$. The percentage adjustment in exports will exceed the percentage adjustment in prices if excess supply is elastic. It will equal the percentage price change if excess supply is unit elastic and will be less than the percentage price change if excess supply is inelastic. Thus, the response of exports is es-

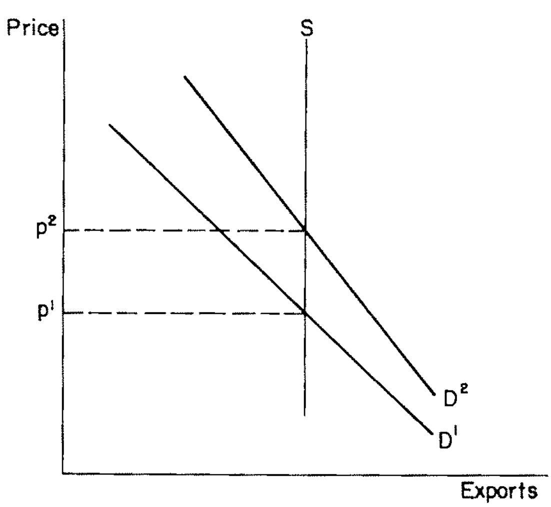


Figure 1

[1] Bredahl and Womack essentially are interested in comparing the comparative effect of exchange rate fluctuation on systems characterized by free and restricted trade. Their analysis, therefore, does not focus on the more general problem that is the topic of this paper. Their conclusions, however, are interesting as they find that, depending on its source, exchange rate fluctuation may have greater impacts on systems characterized by restricted trade than on systems characterized by free trade.

[2] The literature is not consistent as to how the exchange rate is defined. In the context above, e is defined as γ_i/p_i so that an increase in e means that it takes more units of the importer's currency to get one unit of the exporter's currency or that the exporter's currency has appreciated.

[3] To see this more clearly, note that in equilibrium

$$\epsilon_i = \frac{(\partial g/\partial p_i)p_i}{Q_i} \quad \eta_i = \frac{(\partial f/\partial \gamma_i)ep_i}{Q_i} = \frac{(\partial f/\partial \gamma_i)\gamma_i}{Q_i},$$

and

$$\frac{\eta_i}{\eta_i - \epsilon_i} = \frac{-(\partial f/\partial \gamma_i)ep_i}{(\partial f/\partial \gamma_i)ep_i - (\partial g/\partial p_i)p_i}.$$

The result follows directly.

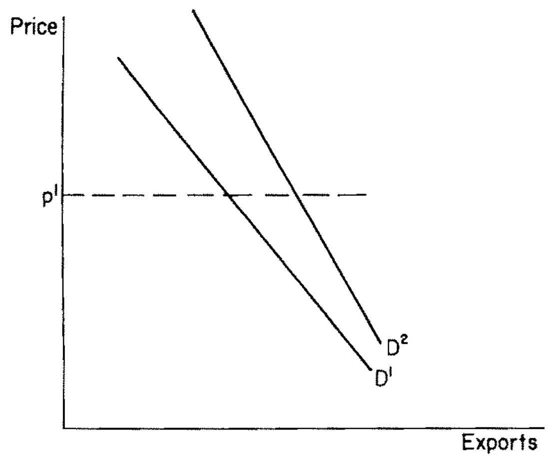


Figure 2

sentially limited by the elasticity of excess supply as is clear from figures 1 and 2. If excess supply is elastic, the price rise due to the devaluation will call forth a more than proportional increase in supply, and the percentage increase in exports will exceed the percentage increase in price.

A More General Theoretical Framework

The model and the results outlined in equations (1)–(6) rest on some very strong assumptions. In some cases, the assumptions are recognized; but conclusions and empirical tests are carried out in seeming ignorance of their implications. In point of fact, the excess demand relation specified in equation (1) can be derived from standard neoclassical demand theory only under the assumption of zero cross-price elasticities between the traded agricultural commodity and all other goods for which prices are not constant or under other similarly restrictive assumptions.

To see this, recall that neoclassical demand functions are obtained by maximizing an individual's preference function subject to a budget constraint. The individual's demand for any commodity is thus a function of all other prices and the consumer's income. Making the assumption that some appropriate method of aggregating individual consumer demands exists, excess demand as specified in equation (1a) should be taken as a function of all prices and aggregate income in the importing country (see Lau). Hence, it is clear that (1a) should be respecified as

$$D_i = f(\gamma, M), \tag{7}$$

where γ is a vector containing the prices of all n commodities in the importing country and M is income.[4] Similarly, supply functions, especially at the aggregate level, should be specified as functions of the prices of all alternative production possibilities as well. More generally, since the supplies and demands in (1) are excess functions, supply and demand interactions may lead to income elasticities as well as cross-price elasticities in both the importer's and exporter's cases. Replace (1b) with

$$S_i = g(\mathbf{p}), \tag{8}$$

where $\mathbf{p}$ is a vector containing the prices of all n commodities in the exporting country.

For simplicity of exposition, assume that all goods are traded. Although somewhat unrealistic, this assumption does not change the qualitative results of the analysis. It does, however, considerably simplify the notation. The economy of notation hopefully contributes to the heuristic content of the argument. In the absence of barriers or distortions in trade, the law of one price holds in equilibrium for all commodities, i.e.,

$$\gamma = \mathbf{p}e. \tag{9}$$

Differentiating this equilibrium condition under the assumption that $dM = 0$ obtains (see the Appendix for a derivation)

$$\frac{dp_i}{de}\,\frac{e}{p_i} = \bar{\zeta}_i = \zeta_i + \frac{\zeta_i}{\eta_i}\left[(\eta^*_i)'(\mathbf{s} + \zeta^*_i) - (\epsilon^*_i)'\zeta^*_i\right], \tag{10}$$

where ζ_i is the partial exchange rate elasticity defined by equation (4), $\bar{\zeta}_i$ is the total exchange rate elasticity (which takes account of adjustments in other markets), η^*_i is an $n - 1$ column vector of cross-price elasticities of demand, ζ^*_i is an $n - 1$ column vector of exchange rate elasticities of the cross prices (denominated in exporter's currency), $\mathbf{s}$ is an $n - 1$ column vector of ones, and ϵ^*_i is an $n - 1$ column vector of cross-price elasticities of supply. Upon further imposing homogeneity conditions for excess supply and demand,

$$\eta_i + (\eta^*_i)'\mathbf{s} + \omega = 0$$
$$\epsilon_i + (\epsilon^*_i)'\mathbf{s} = 0,$$

[4] Bredahl has extended the simple one good linear excess demand and supply model to account for the existence of a substitute commodity. His analysis centers on comparing the free trade and restricted trade case and, unlike the present paper, gives no attention to the n-good free trade case. An area worth investigating would be the comparative effect of exchange rate devaluation in the n-good free and restricted trade cases.

where ω is the income elasticity of excess demand for good i, the relationship in (10) can be rewritten as

$$(11)\ \tilde{\zeta}_i = \zeta_i - \frac{(\eta^*_i)'\zeta^*_i - (\omega + \eta_{ii}) - (\epsilon^*_i)'\zeta^*_i}{\eta_{ii} + (\epsilon^*_i)'s},$$

since

$$\frac{\zeta_i}{\eta_{ii}} = \frac{\left(\dfrac{-\eta_{ii}}{\eta_{ii} - \epsilon_{ii}}\right)}{\eta_{ii}} = -\frac{1}{\eta_{ii} - \epsilon_{ii}} > 0.$$

By usual assumptions, the absolute value of $\tilde{\zeta}_i$ will thus be greater than that of ζ_i if, and only if, the term in brackets in (10) or the numerator in (11) is negative. It is also clear that more inelastic excess demand (with respect to own price) implies a greater difference between $\tilde{\zeta}_i$ and ζ_i. From (10) and (11), it should be clear that there is no a priori reason to restrict $\tilde{\zeta}_i$ to the closed interval $[0, -1]$.[5]

For example, consider the implications of the assumption in (1a), i.e., zero cross elasticities of demand. More specifically, this may correspond to a case of a staple commodity which is consumed in essentially fixed amounts regardless of usual price variations. Also, suppose the commodity is a substitute or is unrelated in supply with all other commodities (but a substitute with at least some). In this case $\eta^*_i = 0$ and $\omega + \eta_{ii} = 0$, so equation (11) becomes

$$\tilde{\zeta}_i = \zeta_i + \frac{(\epsilon^*_i)'\zeta^*_i}{\eta_{ii} + (\epsilon^*_i)'s}.$$

Hence, if exchange rate devaluations are to some extent inflationary for the supply substitutes (indicated by corresponding negative coordinates in ζ^*_i), then $(\epsilon^*_i)'\zeta^*_i > 0$ so that $|\tilde{\zeta}_i| > |\zeta_i|$, i.e., price is affected to a greater extent than implied by the overly simplified model described in (1). (Homogeneity implies $\eta_{ii} + (\epsilon^*_i)'s = \eta_{ii} - \epsilon_{ii}$ so that the denominator in (11) is negative.) Thus, the associated argument that the percentage change in price is less than the percentage exchange rate movement is invalid. Furthermore, it is interesting to note that the conditions which guarantee this result, while not applying exactly, are to some extent approximations describing U.S. agricultural grain exports. Some individual U.S. grains, such as wheat, are staple food items with low demand elasticities but strong substitution possibilities in supply.

In the context of figures 1 and 2, this can be explained by noting that the more general model described by equations (7), (8), (9), and (1c) treats all other prices, the exchange rate, and income as demand shifters and all other prices and the exchange rate as supply shifters. By changing other prices, a devaluation will cause shifts of both the supply and the demand curves. Further, demand shifts need no longer be pure percentage shifts as is the case when the exchange rate is the only demand shifter. Clearly, there is no a priori reason to expect the price or quantity change to be less in percentage terms than the change in the exchange rate.

In more general terms, it is difficult to evaluate (10) or (11) without knowing the magnitudes and signs of the elasticities. But, in general, if goods with nonzero cross-price elasticities of demand tend to be complements (substitutes) in demand and have prices which are relatively exchange rate inelastic (elastic), then $\tilde{\zeta}_i$ will tend to be larger in absolute terms than ζ_i. Similarly, if the goods with nonzero cross-price elasticities of supply tend to be supply substitutes, then $\tilde{\zeta}_i$ will tend to be larger in absolute terms than ζ_i.

A problem closely related to the one discussed above is the responsiveness of excess demand to exchange rate fluctuation and exporter price fluctuation. It is clear that the simple model forces a price change to have the same effects as an exchange rate change so that the elasticity of excess demand with respect to a change in the exporter's price η_{ii} is equal to the exchange rate elasticity of excess demand α_i, i.e., $\eta_{ii} = \alpha_i$. In the extended model represented by equations (7), (8), and (1c), however, it is clear that

$$(12)\qquad \alpha_i = \eta_{ii} + (\eta^*_i)'s = -\omega.$$

The second equality follows from the fact that excess demand functions are homogeneous of degree zero in prices and income. Therefore, a devaluation by an exporter is equivalent to a proportionate decrease in all prices or a proportionate increase in the importer's income.[6] Hence, unless $(\eta^*_i)'s$ is identically zero

[5] Several studies carried out at the macrolevel—e.g., Dornbusch—suggest that the impact of a devaluation on the aggregate price level of traded goods is to increase aggregate price relatively less than the percentage of devaluation. The present results show in contrast, however, that similar conclusions may not be valid for all individual traded goods.

[6] The authors are indebted to Maury Bredahl for the observation of the equivalence of the income effect and the elasticity of excess demand with respect to the exchange rate. It should be noted, however, that this result only holds when all goods are traded.

(which except in special cases implies zero cross-price elasticities between good i and other traded goods), the elasticities are different in the extended model). Of course, (η^*_i)'s could be zero if negative and positive cross-price elasticities exactly balance one another, but this would not seem to be a very important exception from the standpoint of a priori justification since the condition, once satisfied, would almost certainly cease to hold after a small variation in any single price corresponding to a nonzero cross-price elasticity.

Implications for Empirical Work

As a practical matter, it has long been recognized that problems of multicollinearity, degrees of freedom, and sheer data requirements prohibit the estimation of relationships like (7) and (8) involving all cross-price effects. As will be seen below, most empirical work on the effects of devaluation has concentrated on the estimation of import demand (excess demand) relationships; hence, attention will be directed to the problem of estimating equations of the type in (7). One course often taken is simply to assume, as does the first model presented above, that excess demand is a function of own price alone and of no other prices. As pointed out earlier, such an assumption presupposes that exchange rate movements and own-price movements in the exporting country have the same effect on excess demand. The results of any empirical analyses of exchange rates based on these assumptions, to a large extent, thus can be influenced by the assumptions. Expressions like (12) show that such specifications are inappropriate without prior validation. More importantly, such improper specifications can lead to confounding the role of prices and exchange rates so that both elasticities are estimated incorrectly.

Apart from these considerations, there is further reason to believe that exchange movements should be differentiated from market price movements. Orcutt, in a classic paper, has hypothesized that economic agents react more quickly to exchange rate fluctuations than to market price changes in a world characterized by fixed exchange rates. When exchange rates are inflexible, consumers perceive a devaluation or revaluation as being more permanent than short-term price changes. Also, in this case, exchange rate movements usually involve much larger percentage changes than market price fluctuations taking place in a similar short time interval. On the basis of these two points, it would not be surprising if adjustment to exchange rate changes in a fixed-rate system was faster than to market price changes. Junz and Rhomberg have presented evidence that does not tend to favor Orcutt's hypothesis, but Wilson and Takacs have more recently presented empirical results supporting Orcutt. Thus, it seems that Orcutt's hypothesis should be given consideration prior to any empirical investigation of the devaluations of the early 1970s.

Empirical Devaluation Studies

In the context of the above discussion, this section critically reviews some of the empirical studies that have been done in recent years on the effect of the exchange rate devaluation on the markets for agricultural products.

Clark appears to have been among the first to investigate empirically the impact of the devaluations of the dollar. His results are interesting in that they imply a much larger relative effect of the devaluations on agricultural goods than on manufactured goods. Clark attributes only part of the rise in agricultural prices to the depreciation of the exchange rate because exchange rates were constrained to have the same effect as price. Hence, the estimated exchange rate impacts on prices were unduly restricted.

Vellianitis-Fidas has presented empirical results centered on agricultural exports on the basis of which she claims that the exchange rate has had little impact on agricultural exports. But Vellianitis-Fidas' results appear to have limited significance because her empirical investigation has no underlying theoretical structure. Her only rationale is that "the purpose of this analysis is not to build a model explaining U.S. agricultural exports, but simply to look at the significance of one variable—the exchange rate" (p. 108). Classical statistical theory suggests that a variable cannot be declared significant or insignificant without having any clear idea of the true model since ordinary least squares procedures are not always valid.

Greenshields studied the impact of changes in the yen-dollar exchange rate on U.S. grain and soybean exports to Japan. He estimates equations for wheat, corn, and soybean import

demand by Japan. His general model (functional forms differ) is

$$(13) \qquad Y = Y(X_1, X_2, X_3),$$

where Y is the annual commodity import, X_1 is the commodity import price index, X_2 is private consumption expenditure, and X_3 is a domestic supply variable. Equations of the type (13) were estimated by ordinary least squares (OLS). An apparent econometric problem with this approach is that Y and X_1 are probably jointly dependent, and application of OLS may yield inconsistent estimates of the parameters of (13).

After estimating (13), Greenshields obtains estimates of what yen prices would have been had there been no exchange rate changes in the period 1971–73. Then under the "additional assumption . . . that response to exchange rate changes are analogous to responses to relative price changes in general" (p. 3), Greenshields uses these adjusted prices and the estimated equations to estimate the impact of the devaluation of the dollar on the exports of these commodities to Japan. Not surprisingly, he determines under this assumption that the devaluation had little impact on these exports.

As discussed at length in the previous section on the theoretical literature, Greenshields' assumption imposes implicit conditions about cross-price elasticities which appear to be unduly restrictive. Also, in view of Orcutt's hypothesis and the empirical support it has received, it seems that this is an assumption (i.e., response to exchange rates is analogous to response to own price) that cannot be made without further empirical support. The validity of the assumption of zero cross-price elasticities seems particularly questionable for the case of Japan. Japan's decision on how much grain to import from the United States is probably determined to some extent by the volume of other imports from the United States and, also, to some extent by the volume of its exports to the United States, both of which would be affected by an exchange rate devaluation.

Johnson, Grennes, and Thursby, in a recent paper in this *Journal,* have also investigated the effects of the devaluations in the early 1970s on the price of wheat in the United States. Their model postulates that exports of wheat from country j to country i can be represented as

$$(14) \qquad Q_{ij} = f(p_{ij}^D, Z_i) \qquad i, j = 1, \ldots, n$$
$$p_{ij}^D = rp_j^S + t_{ij},$$

where the supply side is taken as exogenous, Q_{ij} is quantity of wheat from country j consumed in country i, p_{ij}^D is consumer price in country i of wheat from country j, Z_i is a vector of exogenous demand shifters for country i, p_j^S is the supply price in country j, t_{ij} is an exogenous price shifter, and r is the exchange rate between country i and j. The model is one of export flows that differentiates by country of origin and country of destination.

As should be clear from (14), Johnson, Grennes, and Thursby assume an empirical model equivalent to that outlined in equations (1). In such a model one would not expect the price in the United States to change by more than the percentage of devaluation; in fact, given the specification, one would be surprised if it changed as much. Johnson, Grennes, and Thursby derive a reduced form for the model; and from the reduced form, they estimate that the 10% devaluation of the dollar led to approximately a 7% increase in domestic wheat prices. The gist of their article is that other factors such as tariff policies by the EEC had larger impacts on U.S. domestic wheat prices than the devaluation. The qualitative results of their analysis may well be correct, but the quantitative magnitudes are certainly open to question. That is, before their results are accepted, it must be demonstrated that, under a system of fixed exchange rates, it is legitimate to restrict the a priori exchange rate elasticity of exporter price to the closed interval $[0, -1]$ and that it is appropriate to force exporter price and exchange rate changes to have the same relative effect on excess demand in the importing country. This is especially important because Johnson, Grennes, and Thursby concentrate their analysis on the devaluation effect for the European Community and Japan both of whom trade more than just wheat with the United States; hence, cross-price effects may be substantial. It should be added, however, that their model which takes account of trade restrictions would be a more appropriate setting for examining the importance of exchange rates than the more simple empirical models if sufficient flexibility of exchange rate elasticities *vis-à-vis* price elasticities were allowed.

An Alternative Empirical Approach

Perhaps a more fruitful approach with regard to exchange rate flexibility is to make some explicit assumptions about the separability of

the utility functions underlying the import demand equations. Specification of a weakly separable utility function permits the assumption of a two-stage budgeting process on the part of consumers. Consumers are assumed to be able to divide commodities into several groups. In the first stage of the budgeting process, consumers split total expenditure into group expenditures; and in the second stage, they split group expenditure into individual commodity expenditures. Demand functions derived from such a process depend upon the prices of other commodities within the group, price indices for the other groups, and total income. This leads to a considerable reduction in the number of parameters to be estimated while not unduly restricting exchange rate and own price movements to have the same effect on excess demand. Similar separability arguments apply to the supply side as well.

Clearly, one can assume with less loss of generality than the approaches discussed above (in which all other commodities are essentially ignored) that commodities are separable into three groups—the good in question, all other traded goods, and nontraded goods. Thus, one possibility is to construct separate price indices for "all other" traded commodities and all nontraded commodities, weight the "all other" commodity index by the exchange rate, and include both along with the own price (in the importing country) as separate regressors. This approach allows for fluctuations that arise directly from exchange rate variation as well as from price movements in the exporting country. It should be noted, however, that standard price indices are not appropriate for this purpose since the standard baskets of goods used in computing indices are not delineated along the lines of traded and nontraded goods. Furthermore, the trade indices which are available use weightings based on traded quantities rather than on quantities consumed or produced in importing countries. Thus, because of lack of appropriate indices, this approach has apparently not been used.

A more pragmatic alternative which has been used is to treat the exchange rate as a price index for all other traded goods. In the case where all other individual price movements are unimportant in the overall indices for traded and nontraded goods, this approach would, indeed, simplify to using only the two variables—own price and exchange rate—in explaining price effects on export demand. As suggested above, however, own price would appear denominated in the importer's currency. One can note that this is not the case with the empirical studies discussed below.

In addition to the above discussion relating to separability, the Orcutt hypothesis tends to suggest that it may be appropriate to include the exchange rate directly in excess demand and import equations to allow for the differential effects of exchange rate and price fluctuations. If there are differential adjustments to price and exchange rate movements, then it is clear that one variable, say, deflated price, cannot be used to represent both effects.

Fletcher, Just, and Schmitz have applied this principle to an agricultural market by including exchange rate as a separate regressor. Their results indicate that the exchange rate had dramatic impacts on the level of exports of U.S. wheat and that U.S. wheat price is exchange rate elastic. Meilke and de Gorter also include a weighted exchange rate as a separate regressor in an equation explaining U.S. corn exports. Their results similarly indicate that the exchange rate is an important factor affecting the level of corn exports.

Alternatively, Gallagher, Bredahl, and Lancaster have suggested inflating the income term in the excess demand function. This is strictly appropriate only when all goods are traded and when the excess demand function is specified empirically to comply with the usual homogeneity conditions for excess demand functions. For example, inflating the income term in a linear, excess demand function where there are nontraded goods may well introduce some bias. Like the approach suggested above, however, this may prove to be a more attractive alternative than simply restricting the price and exchange rate to have the same relative effect on excess demand.

Concluding Remarks

The arguments in this paper suggest that the usual approach to evaluating the effects of exchange rate movements on U.S. agricultural commodities are unduly and unjustly restrictive. Using a more general model of excess demand and supply, one finds that the response to exchange rate of both price and quantity exported can be greater (or less) than the overly restrictive models suggest. In fact, conditions surrounding U.S. agricultural trade tend to approximate those conditions that result in larger exchange rate impacts.

Turning to the econometric studies of devaluations, few studies apparently have

realized the importance of the related exchange-rate specification problem. Traditionally, agricultural export models have either excluded exchange rates or simply used them to adjust included prices. However, more generality is attained by including a separate exchange rate variable (involving a weighted price index of other traded goods if feasible) in the regression equation. Empirical studies using this approach have tended to suggest that U.S. agricultural grain prices are exchange rate elastic and that exchange rates are important determinants of agricultural trade flows. If this is the case, then the empirical approach which simply uses own price adjusted by exchange rate may lead to a downward bias on estimates of exchange rate impacts (as well as an associated upward bias on own-price elasticity estimates and income elasticity estimates). This, however, is only a possibility. As a referee points out, if the sum of all cross-price elasticities is positive and the good in question is normal, then the absolute value of own-price elasticity will exceed the absolute value of the exchange-rate elasticity. This condition suggests that restriction of the equality of exchange elasticity and own-price elasticity may lead to upward bias in the elasticity estimate (in absolute value) in some cases.

On a more general level, the results of this paper suggest that much of the problem of measuring exchange rate impacts in agriculture are due to lack of appropriate price indices for certain commodity bundles. Using the concept of separability heuristically, commodities historically have been grouped to construct appropriate price indices for domestic demand analysis. With the increasing importance of international trade in the 1970s, however, a greater need exists for price indices more appropriate for international trade considerations. As pointed out, these variables should include price indices for traded and nontraded goods with weightings pertaining to internal decisions in the importing countries.

[*Received April 1978; revision accepted September 1978.*]

References

Bieri, Jurg, and Alain de Janvry. *Empirical Analysis of Demand under Consumer Budgeting*. Giannini Foundation Monograph No. 30, University of California, Berkeley, Sept. 1972.

Bredahl, Maury E. "Effects of Currency Adjustments Given Free Trade, Trade Restrictions and Cross Commodity Effects." Dep. Agr. Econ. Staff Pap. P76–35, University of Minnesota, St. Paul, Nov. 1976.

Bredahl, Maury E., and Abner Womack. "Effects of Currency Adjustments Given Free Trade and Trade Restrictions." Contributed paper presented at the AAEA meeting, San Diego, Calif., 1977.

Clark, Peter B. "The Effects of Exchange Rate Changes in the U.S. Trade Balance." *The Effects of Exchange Rate Adjustments*, ed. Peter B. Clark, Dennis E. Logue, and Richard James Sweeney, pp. 201–36. Proceedings of a conference sponsored by the Office of the Assistant Secretary for International Affairs, U.S. Department of the Treasury, Washington, D.C., 4–5 Apr. 1974.

Dornbusch, Rudiger. "Devaluation, Money and Nontraded Goods." *Amer. Econ. Rev.* 63(1973):871–80.

Fletcher, Stanley M., Richard E. Just, and Andrew Schmitz. "The Impact of Exchange Rates and Other Factors on North American Wheat Export Demand." *World Food Crisis: Issues and Policy Alternatives*, ed. Gordon C. Rausser. Amsterdam: North-Holland Publishing Co., forthcoming.

Gallagher, Paul, Maury E. Bredahl, and Mike Lancaster. "The Export Market for U.S. Wheat." USDA ESCS CED Work. Pap., 1977.

Greenshields, Bruce F. *Changes in Exchange Rates: Impact on U.S. Grain and Soybean Exports to Japan.* USDA ERS For. Agr. Econ. Rep. 364, July 1974.

Johnson, Paul R., Thomas Grennes, and Marie Thursby. "Devaluation, Foreign Trade Controls, and Domestic Wheat Prices." *Amer. J. Agr. Econ.* 59(1977):619–27.

Junz, Helen B., and Rudolf R. Rhomberg. "Price Competitiveness in Export Trade Among Industrial Countries." *Amer. Econ. Rev.* 63(1973):412–18.

Katzner, Donald W. *Static Demand Theory*. London: Macmillan & Co., 1970.

Kost, William. "Effects of an Exchange Rate Change on Agricultural Trade." *Agr. Econ. Res.* 28(1976):99–106.

Lau, Lawrence J. *Existence Conditions for Aggregate Demand Functions*. Econ. Series Tech. Rep. No. 249., Institute for Mathematical Studies in the Social Sciences, Stanford University, 1977.

Meilke, Karl D., and Harry de Gorter. "A Quarterly Econometric Model of the North American Feed Grain Industry." Paper presented to Economics Branch, Agriculture Canada, Ottawa, 27 Apr. 1977.

Orcutt, Guy H. "Measurement of Price Elasticities in International Trade." *Rev. Econ. and Statis.* 32(1950):117–32.

Schuh, G. Edward. "The Exchange Rate and U. S. Agriculture." *Amer. J. Agr. Econ.* 56(1974):1–13.

Theil, Henri. *Theory and Measurement of Consumer Demand*. Amsterdam: North-Holland Publishing Co., 1975.

Vellianitis-Fidas, Amalia. "The Impact of Devaluation on U.S. Agricultural Exports." *Agr. Econ. Res.* 28(1976):107–16.

Wilson, John F., and Wendy E. Takacs. "Differential Response Lags to Price and Exchange Rate Change in the Foreign Trade of Selected Industrial Countries." Paper presented at the Annual Meeting of Allied Social Sciences Association, Atlantic City, N.J., 16–18 Sept. 1976.

Appendix

Derivation of Equation (10)

Equation (10) is obtained, specifically, by differentiating the equilibrium condition,

$$D_i(\gamma, M) = S_i(p);$$

thus, obtaining

$$\sum_{j=1}^{n} \frac{\partial D_i}{\partial \gamma_j} e\, dp_j + \sum_{j=1}^{n} \frac{\partial D_i}{\partial \gamma_j} p_j\, de = \sum_{j=1}^{n} \frac{\partial S_i}{\partial p_j} dp_j.$$

Rearranging then yields

$$\frac{dp_i}{de} = \frac{1}{\phi_i} \frac{\partial D_i}{\partial \gamma_i} p_i + \frac{1}{\phi_i} \frac{1}{de} \left\{ \sum_{j\neq i} \frac{\partial D_i}{\partial \gamma_j} e\, dp_j + \sum_{j\neq i} \frac{\partial D_i}{\partial \gamma_j} p_j\, de - \sum_{i\neq j} \frac{\partial S_i}{\partial p_j} dp_j \right\},$$

where $\phi_i = \frac{\partial S_i}{\partial p_i} - \frac{\partial D_i}{\partial \gamma_i} e.$

Multiplying by e/p_i and using equation (4), implies

$$\frac{dp_i}{de} \frac{e}{p_i} = \frac{e}{\phi_i} \frac{\partial D_i}{\partial \gamma_i} + \frac{e}{p_i\phi_i} \frac{1}{de} \left\{ \sum_{j\neq i} \frac{\partial D_i}{\partial \gamma_j} e\, dp_j + \sum_{j\neq i} \frac{\partial D_i}{\partial \gamma_j} p_j\, de - \sum_{i\neq j} \frac{\partial S_i}{\partial p_j} dp_j \right\}$$

$$= \zeta_i + \frac{1}{\phi_i} \frac{Q_i}{p_i} \left\{ \sum_{j\neq i} \frac{\partial D_i}{\partial \gamma_j} \frac{e}{D_i} p_j \frac{e}{p_j} \frac{dp_j}{de} + \sum_{j\neq i} \frac{\partial D_i}{\partial \gamma_j} \frac{p_j e}{D_i} - \sum_{j\neq i} \frac{\partial S_i}{\partial p_j} \frac{p_j}{S_i} \frac{e}{p_j} \frac{dp_j}{de} \right\}.$$

The result in equation (10) follows.

Application of a Simulative Approach to Evaluating Alternative Methods for the Control of Agricultural Pests

Katherine H. Reichelderfer and Filmore E. Bender

A microanalytic simulation model of the interrelationships among Mexican bean beetle pest populations, populations of wasps that are parasites of the pest, chemical control inputs, and soybean yield is presented. Points from output response surfaces obtained through simulations of alternative biological and chemical pest control strategies are utilized in conjunction with cost data to construct benefit-cost ratios for each intraseasonal control option studied. Comparison of ratios indicates that biological control of the pest is, by benefit-cost criteria and from both private and social perspectives, a competitive alternative to chemical control.

Key words: benefit-cost analysis, biological control of pests, Mexican bean beetle-soybean simulation, pest management.

In recent years, a number of issues concerning the trade-off relationships between agricultural production and environmental quality have led to an increasing interdisciplinary focus on insecticides as both productive inputs and environmental hazards. Biological research efforts have included numerous studies of alternative pest control strategies which reduce or eliminate the need for pesticide inputs. Furthermore, the development of biological control and integrated pest management schemes have been given increased emphasis. Economic research, however, has focused primarily on the optimization of chemical pest control inputs. This paper summarizes the results of a study where both conventional chemical and alternative pest control strategies were evaluated.

Several approaches to the economic evaluation of pest management strategies have been explored. Headley, who first lent a rigorous definition to the concept of the "economic threshold" within the context of pest damage, devised a univariate abstract model with four basic elements to optimize. Headley focused his attention on the problem of optimizing the rate of a single application of a pesticide for an assumed application date to maximize private benefits. His major conclusion, that the optimal rate is that at which the value of the marginal product of the pesticide input equals its unit price, was consistent with traditional production theory. Hall and Norgaard modified Headley's model to account for optimal intraseasonal timing of an insecticide application. Their findings showed that timing, unlike rate of application, is not a function of crop price or input cost. Talpaz and Borosh expanded the basic model in order to evaluate the efficiency of multiple applications of pesticides within a single growing season. Their results suggested that the optimal number and rates of intraseasonal applications are functions of crop price and input cost.

All of the studies cited utilized a marginal approach to evaluating or optimizing pest management strategies. While this approach is a useful one when examining the allocation of resources to pest control, certain biological realities complicate its practical application. The marginal benefit of a pest control action may be a function of the size and age-structure

---

Katherine H. Reichelderfer is an agricultural economist, Natural Resource Economics Division, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, and Filmore E. Bender is a professor in the Department of Agricultural and Resource Economics, University of Maryland.

Scientific Article No. A2566, Contribution No. 5604 of the Maryland Agricultural Experiment Station.

The study was funded, in part, by the U.S. Environmental Protection Agency under their contract no. 68-01-1938.

The authors wish to thank J. C. Headley, W. G. Ruesink, and an anonymous reviewer for their comments on an earlier draft of this article.

of the pest population, the size and age-structure of nontarget species' populations, the stage of development of the crop which is to be protected, and a variety of other factors (e.g., weather) which are independent of the number of units of control action applied to the system. An attempt to establish the productivity of biological control would be highly complicated by its biological interrelationship with the pest population. A further limiting factor is embodied in current federal regulations which prohibit the use of pesticides at any dosage other than a recommended rate of application. In instances where a single application of chemical constitutes the control action, only the time of that application is variable. The producer is not free to vary the intensity of application of insecticides as is implied by previous marginal analyses (Headley; Hall and Norgaard; Talpaz and Borosh; Regev, Gutierrez, Feder).

While the reviewed evaluation methods are still excellent bases upon which to elaborate, they are highly abstract and, as such, they cannot take into account many of the biological processes which have definite economic implications. For example, the use of a single, generalized pest-population growth curve (Headley, Hall and Norgaard, Talpaz and Borosh) distorts the economic evaluation of pest control action by ignoring the possibility that, at some points in time, a large proportion of the pest population may exist in a stage (e.g., pupal) in which it is less vulnerable to pesticide application. In addition, assumptions to the effect that the pest population is homogeneous may distort evaluation/optimization results. Where the pest undergoes a pattern of development in which it proceeds through a number of distinct growth stages, there may exist, in effect, a situation of interdependent yet multiple pests, each with varying effects upon the crop and different responses to control action.

The use of a single, generalized damage function may be another form of misspecification in that it does not reflect the fact that the crop may be more or less vulnerable to insect damage depending upon its stage of development. These are just a few aspects of the relationship between a pest and crop which cannot be accounted for in the mathematical models utilized to date. Hall and Norgaard (p. 201) have aptly pointed out that, "as these additional factors are introduced, mathematical models rapidly become unmanageable."

Statement of the Problem

The Mexican bean beetle (MBB) is a major insect pest of soybeans. Soybean growers in the Delmarva (Delaware-Maryland-Virginia) production region have had access to a number of different methods by which to control MBB. These include various conventional patterns of chemical control, prescribed spraying pest management, biological control by a parasitic wasp, and a strategy that integrates the use of the last two alternatives. The question faced by the researchers was: which of these MBB control options can be expected to yield the highest private and social returns to expenditure on control? Each control alternative was evaluated in terms of the private and social benefits which were estimated to result from its use as compared to the alternative of no control action.

Alternative Methods for the Control of Mexican Bean Beetles

Two different insecticides are commonly used, either singly or in combination, to control MBB on soybeans in Delmarva. Disulfoton, a systemic insecticide, is frequently utilized as a prophylactic control measure. Carbaryl is used as its need is assessed by individual producers, on a scheduled basis, or as a component of a prescribed spraying strategy. In 1974, 38.6% of total Delmarva soybean acreage was treated with insecticides to control the MBB. Carbaryl and disulfoton were used on 64% and 36% of the treated acreage, respectively, and approximately 25% of that acreage received two applications of insecticides (Dively). This observed pattern of control was assumed to be representative of conventional chemical control of the MBB on soybeans in Delmarva.

In Maryland, the University of Maryland Prescribed Spraying Pest Management Program is currently operative for the control of MBB on soybeans. This particular program utilizes reports from trained field scouts on estimated levels of percentage of defoliation in area soybean fields. Its strategy involves no use of disulfoton and it advocates the use of carbaryl only when the observed (through sampling) percentage of defoliation of the soybean crop reaches a predetermined "defoliation action threshold" which is defined by the University of Maryland Pest Management

Program as "the amount of leaf loss allowed at each (soybean) maturity stage before yield is affected." These threshold levels are determined by the University of Maryland pest management specialists and differ among the ten stages of soybean growth. They are used as the basis for determining whether or not and when to apply carbaryl for MBB control.

Biological control is achieved through the controlled use of a parasitic wasp. The wasp, *Pediobius foveolatus* (Crawford), has successfully been used to suppress MBB populations on soybeans (Stevens, Steinhauer and Coulson). It is specific to MBB and affects individuals by ovipositing into the body of third and fourth (occasionally second) instar MBB larvae. The development of immature wasps within an MBB larva kills that larva and provides a shell in which the new generation of wasps develops to maturity. The use of *Pediobius foveolatus* populations as a measure for the control of Mexican bean beetles on soybeans in Maryland was first tested in 1972–74. The average percentage of parasitism of Mexican bean beetle larvae achieved in soybean fields sampled in twelve Maryland counties reached 84% by the latter part of the 1974 growing season (Stevens, Steinhauer and Coulson). The use of the parasite was subsequently incorporated into the University of Maryland Soybean Pest Management Program. The Maryland State Department of Agriculture currently provides the funding for rearing and distribution of the parasite. The wasps cannot overwinter in temperate climates and must be released annually. The state program, therefore, operates on an annual basis. Each soybean grower participant in the parasite program provides a "nurse plot" of garden variety beans, at a variable cost plus opportunity cost of approximately $50.00, to facilitate the early release of parasites directed for use on soybean acreage. Each nurse plot is approximately 5,445 square feet and serves 200 surrounding acres of soybeans.

A Simulative Approach to Evaluating Pest Control Strategies

A microanalytic simulation approach was utilized in this study to provide data for the economic evaluation of alternative methods for the control of MBB on soybeans in Delmarva. Simulation of this sort specifies each of the basic components of a system and, in doing so, avoids the distortions which may arise from abstraction (Orcutt; Shubik; Bender; Johnson and Rausser). The specification of all the biological, physical, and economic elements that have an impact on pest management strategies greatly increases the complexity of the model and usually precludes direct optimization.

A computer simulation model was developed in order to describe the physical production relationship between MBB control inputs and soybean yield under different exogenous conditions defining the MBB pest problem and type of control action taken. The model simulates a per acre, intraseasonal dynamic system. The output of the model is deterministic. The values assigned to the input variables are fixed and based upon averages. The output for a simulation of the system under any one set of inputs is single valued and, invoking certainty equivalence, represents average values.

There are five major components of the model developed to simulate soybean production in the presence of a MBB population. The first of these is that which describes the growth of the MBB population over time. Given an initial, immigrating population of adult beetles and the day on which that population is assumed to migrate into a field as exogenous variables, the number of MBB in each of their insect growth stages can be determined for each of the relevant days over which the simulation takes place. Since the MBB develops through four distinct larval stages (first through fourth larval instars) among which soybean leaf consumption rates, daily natural mortality rates, and susceptibility to parasitism differ, cohorts of individual beetles are followed from their egg stage through the four larval stages and an immobile, nonfeeding pupal stage, to their adult stage. This was accomplished through the use of parameters relating to the life cycle of the MBB which were derived from entomological literature and communication with researchers working with the pest. Given the size of an initial population of invading adult beetles and the date of infestation, the number of eggs laid on a given subsequent date is determined by:

$$E_{jt} = \sum_{g=1}^{j-1} F_g A_{gt} R_g,$$

where E_{jt} is the total number of eggs laid on day t for the jth MBB generation; F_g is the proportion of females in the population of gth

generation beetles; A_{gt} is the number of gth generation adult beetles of egg laying age on day t; and R_g is the average daily egg laying rate for gth generation adult beetles. The number of beetles in each subsequent life stage on each given day is determined by

$$B_{ijkt} = (B_{i-1,\,jH,\,t-1})(S_{i-1,\,t-1}) - \left[(P_{i-1,\,j,\,H-4,\,t-5})\prod_{r=1}^{5} S_{i-1,\,t-r}\right],$$

when $k = 1$, and

$$B_{ijkt} = (B_{ij,\,k-1,\,t-1})(S_{i,\,t-1}) - \left[(P_{i-1,\,jh,\,t-5})\left(\prod_{r=1}^{k-1} S_{i,\,t-r}\prod_{w=k}^{5} S_{i-1,\,t-w}\right)\right],$$

when $k = 2, 3, \ldots, K$ and $h = H + (k - 5)$, where B_{ijkt} is the number of jth generation MBB in the ith life stage which are k days old within the ith stage on day t; K is the average maximum number of days the MBB remains in the ith life stage; H is the average maximum number of days the MBB remains in the $(i - 1)$th life stage; S_{it} is the daily survivorship rate for MBB in the ith life stage on day t; and P_{ijkt} is the number of jth generation MBB which are k days old within the ith life stage and are parasitized on day t. Larvae were classified by age within stage due to the assumption that parasitized larvae develop normally during the five days that follow initial parasitization and precede death due to parasitization.

The second component of the model is that which describes the growth and development of the soybean crop from the day of planting through its tenth and final stage of growth. The pattern of the crop's growth is based solely on its biological characteristics and is independent of the growth of the pest population. The data upon which the simulation of soybean growth and development were based were estimated by McAvoy for York variety soybeans grown in Delmarva. McAvoy determined the mean leaf surface area and average duration for each of the ten standard soybean growth stages. A generalized growth curve was constructed from McAvoy's data utilizing the assumption that the rate of growth of leaf surface area was constant within each soybean growth stage.

The third component of the model describes the consumption of soybean leaves by MBB. It is a function of the size and age structure of the MBB population at each period of time (day) and the consumption rates of the MBB in each of its various growth stages.

The fourth component simulates soybean defoliation over time. This process is a function of both leaf consumption by MBBs and the soybeans' growth and development. In the dynamic system, both available leaf surface area and the amount of leaf consumption by the pest population are constantly changing over time. The model accounts for this change.

The last major component of the model is that which describes the loss of soybean yield as a direct function of soybean defoliation. Eight different equations regressing yield on defoliation were used to express the varying response of the crop to defoliation occurring at different stages of the crop's development. Equations estimated by Stone and Pedigo for defoliation occurring during the odd-numbered soybean growth stages were used in conjunction with those estimated by Thomas et al. for the later, even-numbered stages. All were of the general form:

$$Y = aD_t + bD_t^2$$

where Y is the percentage of yield loss and D_t is the percentage of defoliation at time t. Each of the eight equations has a different combination of values for the coefficients a and b. Percentage yield loss at harvest was the relevant output of the simulation.

Any simulated pest control action acts directly upon the portion of the model describing the growth of the MBB population. Chemical control was simulated by altering the parameters which defined the MBB mortality rates and were a necessary component of the description of the pest's population dynamics. The effects of biological control also act directly upon that portion of the model devoted to the MBB population dynamics. Biological control, however, was a function of the growth of the parasite population from an initial immigrating population level. This relationship necessitated the development of a submodel to describe the parasite's population dynamics.

The parasite population submodel was partially dependent upon the MBB's population growth since the parasitic wasps depend upon the beetles as host of their reproductive process. The submodel generated values representing the number of MBB larvae available for initial parasitization, and those parasitized, by the following equations:

$$N_{ijkt} = B_{ijkt} - \left[\sum_{r=0}^{3} (P_{i-1,j,H-4,t-1-r})(S_{i-1,t-1-r}) \right],$$

when $k = 1$, and:

$$N_{ijkt} = B_{ijkt} - \left[\sum_{s=1}^{k-1} (P_{ij,k-s,t-s})(S_{i,t-s}) + \sum_{r=k}^{4} (P_{i-1,j,H+k-r,t-r})(S_{i-1,t-r}) \right],$$

when $k = 2, 3, \ldots, K$ and where, for each equation: N_{ijkt} is the number of jth generation MBB which are k days old within the ith life stage and have never been parasitized as of day t.

$$P_{ijkat} = (W_{at})\, MO\left(\frac{N_{ijkt}}{Q_t}\right),$$

where P_{ijkat} is the number of jth generation MBB larvae which are k days old within the ith life stage and are parasitized by wasps of age a on day t; O is the average daily rate of oviposition by wasps; M is the proportion of wasp population assumed to be female; W_{at} is the number of wasps of age a on day t; and Q_t is the total number of all MBB larvae available for initial parasitization and reparasitization at time t. The total number of larvae available for parasitization will normally be all living (whether previously parasitized or not) third or fourth instar larvae. The parasite was assumed to have no preference between nonparasitized and parasitized but not yet dead larvae or between third and fourth instar larvae. The population of MBB larvae available for parasitization was assumed to include second instar larvae only when the number of third plus fourth instars equaled less than 10% of all larvae. The program directs the simulation of parasitization of second instar larvae when that condition is generated. No parasite preference among second, third, and fourth instars was assumed for that case.

$$R_{ijkt} = (W_{at})\, MO\left[\frac{B_{ijkt} - N_{ijkt}}{Q_t}\right],$$

where R_{ijkt} is the number of jth generation MBB larvae which are k days old within the ith life stage and are reparasitized on day t.

The phrase "successful parasitization" refers to those cases in which the generation of wasps developing within the larva survives to adulthood and emerges from the body of the dead larva. The probability that a larva is successfully parasitized was a function of the age of the wasp which initially parasitized it.

$$T_t = \sum_{a} (P_{ijkat})(Z_a),$$

where T_t is the number of larvae successfully parasitized on day t; and Z_a is the probability of successful parasitization by a wasp of age a.

The average lag period between initial parasitization and the emergence of newly developed adult wasps is sixteen days. The number of wasps present on any given day was determined by:

$$W_{at} = V \sum_{r=15+a}^{40} (T_{t-r}),$$

where V is the average number of live wasps produced per successfully parasitized larva. The values of all variables relating to the parasite population were derived from studies by Stevens, Steinhauer, and Coulson and Stevens, Steinhauer, and Elden.

The simulation program was written in FORTRAN IV and was executed on a Univac 1108 computer.[1]

Control Actions Simulated

A total of eleven different types of control was simulated for each of three different input levels of the immigrating MBB population. An original population equal to one adult MBB per row foot was considered a "low" population level, those equal to four and eight per row foot represented "medium" and "high" population levels, respectively.

For each control action where timing was variable, the simulation program calculated the results of the action taken on each of every conceivable application date. The simulation results yielded a complete mapping of the response surface describing the relationship between timing and yield loss for each of these control actions. Figure 1 shows a typical two-dimensional, output response surface obtained in this manner.

For each type of chemical control simulated, chemicals were assumed to be applied only at their recommended rates. The date of simulated disulfoton application was fixed and equal to planting day in accordance with the procedure for its use. Its application was simu-

[1] Copies of the simulation program are available from the authors upon request.

lated by altering the daily mortality rates for the four MBB larval stages for each of the first sixty days of the growing season according to a trend of decreasing efficacy derived from the data of Webb, Smith, and Boswell. A single point relating disulfoton use to yield loss was obtained for each MBB population level.

The timing of carbaryl application is variable. The simulation program was used to calculate yield loss resulting from a carbaryl application, both as the solitary control action and in conjunction with the use of disulfoton, for each day subsequent to the immigration of an initial pest population of each infestation level. Figure 1 is a plotting of one set of 107 points obtained for carbaryl usage and shows the output response to its application to a high level MBB population on varying dates. Optimal dates of carbaryl application, both as a solitary and a complementary control action, were determined from the output response surfaces obtained for each pest infestation level. In addition, forty-five different time combinations of two separate applications of carbaryl were simulated for each MBB population level.

A representative pattern of chemical control was derived from the simulation results for various chemical control actions and the observed area-wide pattern of chemical use against MBB in 1974. The frequency of occurrence of each positive control action, and of the absence of chemical control, was multiplied by the output value for the simulated optimally timed application of that action (or nonaction) and those products were summed across actions to obtain an average per acre yield loss for the region in 1974. The simulation of the current University of Maryland Prescribed Spraying Pest Management Program was achieved by simulating an application of carbaryl on the day(s) on which simulated defoliation reached the appropriate defoliation action threshold.

Figure 1. Output response to the timing of a single carbaryl application to a high pest infestation

Biological control was simulated under the assumption that 264 wasps per acre constitutes a unit input of parasites. (The derivation of this number is discussed by Reichelderfer.) Varying dates for the release of a parasite population of that size were simulated so that a response surface relating time of release to yield loss could be mapped for each pest infestation level.

An integrated pest management strategy was simulated by assuming the optimal date for the release of parasites, as determined from the output response surface obtained through simulation, coupled with the prescribed spraying pest management procedures followed by the University of Maryland program.

Uncontrolled MBB populations of all three levels were simulated as a control against which the other simulations could be compared.

Significant Simulation Results

The soybean yield loss output of the simulation of 1,158 different control action-pest infestation state of nature combinations yielded several notable conclusions. First, it was found that the physical productivity of a unit input of chemical or biological control varied according to the timing of its application. The mapping of output response surfaces (e.g., figure 1) indicated that the optimal timing of the application of either carbaryl or the biological control agent was independent of crop price and input cost. This was consistent with the findings of Hall and Norgaard. A comparison of the output response surfaces obtained from simulations of the various control actions indicated that: for a given date of application and at assumed units, the physical productivity of chemical control inputs exceeds that of biological control inputs; and that the productivity of a unit input of a given control agent, for a given date of application, was greater for its implementation on higher levels of MBB infestation. The last result was consistent with the findings of other researchers (e.g., Hall and Norgaard; Talpaz and Borosh; Regev, Gutierrez, Feder) concerning the relationship between productivity and the size of the pest population to be controlled.

Benefit-Cost Ratios for MBB Control Alternatives

The value of a given control action was determined in the following manner:

$$V_{mn} = P(c_m Y - d_{mn} Y),$$

where V_{mn} is the per acre value of yield benefit of control action n on pest population size m; P is the price per unit of soybeans;[2] Y is the average yield per acre in the absence of a pest population;[3] c_m is the simulated percentage of yield loss in the presence of an uncontrolled pest population of size m; and d_{mn} is the simulated percentage yield loss in the presence of a pest population of size m controlled by action n. For control actions for which timing was a variable, the optima determined from output response surfaces obtained through successive simulations were used to represent percentage of yield loss in calculating the values of their benefits.

The value of the yield benefit of each alternative MBB control action was divided by the private cost of that action's implementation to derive a measure of private return per dollar expended on the action under a specified state of nature regarding the level of pest infestation. The values of the private benefit-cost ratios obtained in this manner are presented in table 1. Of all those control alternatives examined in the benefit-cost framework, biological control was found to have the highest private return per dollar spent on its implementation. Its simulated use as the sole control measure was the only strategy to have yielded a benefit-cost ratio greater than 1.0 for use on the low level MBB infestation. The ranking of pest control options by benefit-cost ratio criteria was equivalent to the ranking obtained by maximum net revenue criteria for low and medium pest population levels. Only in the case of high pest infestation levels did benefit-cost ratio criteria contradict maximum net revenue criteria.

A measure of social returns to expenditure on each alternative was obtained by taking the ratio of the value of the yield benefit of control to the total social cost (opportunity cost plus external cost) of the control action. The value of externalities resulting from all but one of those control strategies which utilize insecticides could not be estimated. Because negative environmental consequences of the chemicals' use were suspected, however, the per

[2] For all simulations, P = \$6.02, the October 1976 mid-month average soybean price received by farmers in Maryland (Maryland Department of Agriculture). The utilization of other prices would change the absolute value of the yield benefits determined but would not alter the relative differences between yield benefit values of alternative MBB control strategies.

[3] For all simulations, Y = 26.81 bushels, the average soybean yield per acre harvested in Maryland between 1966 and 1975 (Maryland Department of Agriculture). The assumption that this represents average yield in the absence of MBB was supported by the Delmarva agricultural extension agents who felt that local MBB control had, in that ten-year period, been initiated at such a high intensity that yield losses due to MBB were negligible.

Table 1. Benefit-Cost Ratios for Alternative Mexican Bean Beetle Control Strategies

	Level of Mexican Bean Beetle Infestation					
	Low		Medium		High	
Control Strategy	Private	Social	Private	Social	Private	Social
One application of carbaryl[a]	0.20	<0.2	1.73	<1.73	6.12	<6.12
Two applications of carbaryl[a]	0.10	<0.10	0.90	<0.90	3.16	<3.16
One application disulfoton	0.16	<0.16	1.73	<1.73	6.33	<6.33
Carbaryl plus disulfoton[a]	0.11	<0.11	0.98	<0.98	3.47	<3.47
Representative pattern of chemical control[b]	0.15	<0.15	1.40	<1.40	4.99	<4.98
Prescribed spraying (grower scouted)	[c]	[c]	0.31	<0.31	2.88	<2.88
Prescribed spraying (hired scouts)	[c]	[c]	0.35	<0.35	3.25	<3.25
Biological control	3.85	0.58	23.84	3.61	69.59	10.54
Biological control plus use of disulfoton	0.23	<0.17	1.97	<1.48	6.75	<5.07
Integrated pest management (grower scouted)	0.44	0.27	2.71	1.65	3.40	<2.86
Integrated pest management (hired scouts)	0.68	0.34	4.20	2.11	3.82	<3.12

[a] Assumes optimal timing of carbaryl application(s).
[b] Based on 1974 use patterns but assuming optimal timing of carbaryl application(s).
[c] Value of yield benefit equaled zero.

acre value of externalities was assumed to be greater than zero. The observed per acre value of honey bee losses arising from the known 1974 insecticide use pattern, 0.06¢ per acre (Reichelderfer), was assumed to be a lower bound to the total value of its externalities. The values of the social benefit-cost ratios obtained using these assumptions concerning social cost are presented in table 1. The ratio obtained for each of those control alternatives utilizing chemical inputs was assumed to represent an upper bound to its actual value since some unknown or underestimated external costs of insecticide usage were assumed to exist. As the difference between the upper bound of the value of the ratio and its actual value was not known, it was difficult to make comparisons among the values of the benefit-cost ratios for the chemical control alternatives. The biological control alternative was found to yield the highest returns to social expenditure on its implementation.

The value of social returns to expenditure on each simulated control action-state of nature combination was less than the value of its private returns to expenditure. As the value of benefits used in the benefit-cost calculations was the same for determining social and private returns, the reason for this difference was the existence or assumption of higher social costs. The social cost of each MBB control method involving insecticide application(s) was higher than its private cost because of the assumption that it creates a negative ownership externality. Those alternatives utilizing biological control had social costs greater than private costs due to the public nature of the finance of area-wide biological control.

When the assumption was made that Delmarva soybean growers assume all costs of biological control and that the growers, through a cooperative effort, can finance the program with the same efficiency as does the state of Maryland, the private benefit-cost ratios for optimally timed biological control were estimated at \$0.50, \$3.13, and \$9.16 for the low, medium, and high simulated MBB infestations, respectively. Under these assumptions, biological control remained the alternative which yielded the highest expected return per private dollar expended.

This study suggests that considerable benefits may be associated with a switch from conventional chemical control to the biological control of MBB on soybeans. Numerous innovative and nonchemical means of pest control have been developed recently for use against a range of agricultural pests, but wide-scale adoption of few of these has subsequently occurred. The evaluation of the potential benefits of the use of any of these alternative methods of pest control may provide an economic incentive for its adoption or an economic explanation for its observed failure in the marketplace. As the parasite program financed by the state of Maryland has received strong support from soybean growers, this study's conclusion that farmers could benefit by the adoption of biological control is substantiated to a considerable degree.

Limitations

The major limitations of the microanalytic simulation model used by the authors were those attributable to the lack of biological data. The MBB model used was not temperature dependent. It would be improved if the relations of the pest's and parasite's population dynamics and the crop's growth and development to temperature, rainfall, and other abiotic factors were known. Given that information, expected values for important variables could be determined according to the probability of the occurrence of certain abiotic conditions.

The application of simulation results could also have been improved by additional biological information on the pest. The examination and comparison of each alternative pest control strategy over specific levels of MBB infestation would not have been necessary if the probability of infestation at each level were known. Had this information been available, the ratio of expected yield benefits to expected control costs could have been calculated for each alternative. These benefit-cost ratios would have been more useful as they would have accounted for some of the risk-related aspects of pest control action decision making.

The intraseasonal nature of this particular study is a further limitation. Both the use of insecticides and the implementation of biological control could have long range positive or negative consequences which were not examined in this analysis because of a lack of data regarding the intraseasonal behavior of the pest, the possible development of pesticide resistance, and the build up of pesticides in the environment over time.

For situations in which only the method and

timing of control are variable, microanalytic simulation can be a useful tool of analysis. Successive simulations can reproduce the probable outcome of each control action and thereby map the entire response surface. In such a situation, a separate optimization algorithm is unnecessary. However, where the number of intraseasonal applications of a given control agent is an important variable or when intraseasonal aspects of control are considered, a dynamic optimization technique would be more appropriate than the simulation procedure presented here. Regev, Gutierrez, and Feder, and Talpaz et al. have applied effectively such optimal control techniques to examine systems in which successive, interdependent pest control decisions must be made.

Conclusions

The application of a specific microanalytic simulation to determining the relative private and social economic advantages of selected alternative methods for controlling MBB on soybeans in Maryland yielded data which were useful to decision makers in both the private and public sectors. It provided evidence that biological control of the pest is more than competitive, from both the private and social standpoints, with its alternative of chemical control. Results also showed that the current private returns per dollar expended on each MBB control option exceeded its social returns per dollar expense due to the existence of externalities and/or the public nature of the finance of biological control.

The authors feel that microanalytic simulation is a useful technique for evaluating pest control alternatives. The simulative approach to generating data on the productivity of pest control actions resolved many of the analytical problems inherent in the marginal analysis of agricultural pest control. The approach utilized in this study enabled the researchers to evaluate alternative pest control strategies on a comparable basis. The adaptability and flexibility of the microanalytic simulation approach enhances its value as a tool for examining the economic aspects of pest control.

[Received May 1978; revision accepted November 1978.]

References

Bender, Filmore E. "Performance of the Broiler Industry—A Simulative Approach." *J. Farm Econ.* 48(1966):1467–76.

Dively, Galen P. *Maryland-Delaware Cooperative Extension Service Blacklight Trap.* Rep. No. 8, University of Maryland, June 1975.

Hall, Darwin C., and Richard B. Norgaard. "On the Timing and Application of Pesticides." *Amer. J. Agr. Econ.* 55(1973):198–201.

Headley, J. C. "Defining the Economic Threshold." *Pest Control Strategies for the Future,* pp. 100–108. Washington, D.C.: National Academy of Sciences, 1972.

Johnson, S. R., and G. C. Rausser. "Systems Analysis and Simulation: A Survey of Applications in Agricultural and Resource Economics." *A Survey of Agricultural Economics Literature Vol. II: Quantitative Methods in Agricultural Economics, 1940s to 1970s,* ed. G. G. Judge, R. H. Day, S. R. Johnson, G. C. Rausser, and L. R. Martin. Minneapolis: University of Minnesota Press, 1977.

Maryland Department of Agriculture. *Maryland Agriculture Statistics: Summary for 1976.* Pub. No. 51, June 1977.

McAvoy, Thomas J. Unpublished data on the growth and development of York soybeans and on soybean leaf consumption rates of Mexican bean beetles. Dep. of Entomology, Virginia Polytechnic Institute and State University, April 1977.

Orcutt, Guy H. "Simulation of Economic Systems." *Amer. Econ. Rev.* 50(1960):893–907.

Regev, Uri, Andrew P. Gutierrez, and Gershon Feder. "Pests As a Common Property Resource: A Case Study of Alfalfa Weevil Control." *Amer. J. Agr. Econ.* 58(1976):186–97.

Reichelderfer, Katherine H. "A Simulative Approach to the Comparison of Alternative Methods for the Control of the Mexican Bean Beetle on Soybeans." Ph.D. thesis, University of Maryland, 1977.

Shubik, M. "Simulation of the Industry and the Firm." *Amer. Econ. Rev.* 50(1960):908–17.

Stevens, L. M., A. L. Steinhauer, and J. R. Coulson. "Suppression of Mexican Bean Beetle on Soybeans with Annual Innoculative Releases of *Pediobius foveolatus.*" *Environ. Entomol.* 4(1975):947–52.

Stevens, L. M., A. L. Steinhauer, and T. C. Elden. "Laboratory Rearing of the Mexican Bean Beetle and the Parasite, *Pediobius foveolatus,* with Emphasis on Parasite Longevity and Host-Parasite Ratios." *Environ. Entomol.* 4(1975):953–57.

Stone, Jay D., and Larry P. Pedigo. "Development and Economic Injury Level of the Green Cloverworm on Soybean in Iowa." *J. Econ. Entomol.* 65(1972):197–201.

Talpaz, Hovav, and Itshak Borosh. "Strategy for Pesticide Use: Frequency and Applications." *Amer. J. Agr. Econ.* 56(1974):769–75.

Talpaz, Hovav, G. L. Curry, P. J. Sharpe, D. W. DeMichele, and R. E. Frisbie. "Optimal Pesticide Application for Controlling the Boll Weevil on Cotton." *Amer. J. Agr. Econ.* 60(1978):469–75.

Thomas, G. D., C. M. Ignoffo, F. D. Biever, and D. B. Smith. "Influence of Defoliation and Depodding on Yield of Soybeans." *J. Econ. Entomol.* 67(1974):683–85.

Turnipseed, S. G., J. W. Todd, G. L. Greene, and M. H.

Bass. "Minimum Rates of Insecticides on Soybeans: Mexican Bean Beetle, Green Cloverworm, Corn Earworm and Velvetbean Caterpillar." *J. Econ. Entomol.* 67(1974):287–92.

Webb, Ralph E., Floyd F. Smith, and A. L. Boswell. "In-Furrow Applications of Systemic Insecticides for Control of Mexican Bean Beetle." *J. Econ. Entomol.* 63(1970):1222–23.

Revenue and Cost Uncertainty, Generalized Mean-Variance, and the Linear Complementarity Problem

Quirino Paris

Symmetric quadratic programming and the linear complementarity problem are presented in the context of a novel interpretation of risk programming. The novelty admits stochastic supplies of limiting inputs, and yet it preserves the linearity of the structural constraints. This formulation is, therefore, a generalization of the traditional mean-variance approach originated with Markowitz's portfolio analysis and extended by Freund to farm planning under uncertain revenues. The specification admits also nonzero covariances between revenues and costs of limiting inputs and allows the computation of risk coefficients associated with a companion chance-constrained problem.

Key words: linear complementarity problem, mean-variance, quadratic programming, risk.

In recent years a number of papers have reproposed in this *Journal* the mean-variance (E-V) approach as a means of dealing with uncertainty both at the firm (Wiens) and the market level (Hazell and Scandizzo). The same method was originally pioneered by Freund about twenty years ago and applied by McFarquar and Camm in more realistic contexts.

As it is usually known, the E-V approach required the restriction of uncertainty to elements of the primal activities (either yields or net unit revenues). The papers by Wiens and Hazell and Scandizzo follow explicitly this tradition. On the other hand, it is generally recognized that an important source of uncertainty is represented by risky supplies of limiting inputs. This area of inquiry has received wide attention since the beginning of the mathematical-programming era. The innumerable contributions associated with it can be classified conveniently into the two categories of stochastic programming—proposed by Tintner, Charnes and Cooper—and of penalty cost programming which is principally associated with the names of Dantzig and Madansky.

Relevant papers about stochastic programming familiar to agricultural economists are those by Cocks, Maruyama, Rae, Hazell and How. They all proposed significant methodological improvements in dealing with farm planning under uncertainty. The apparent drawback of such approaches, however, is that they have not been sufficiently tested by means of empirical studies of some realism, possibly because the required dimensionality of the associated problems is still regarded as a heavy computational burden.

In this paper, a class of hitherto unexplored stochastic programming structures is presented and analyzed. Although the problems admitted by these structures are not among the most general stochastic programs (a nonstochastic linear technology is postulated), they seem to be of considerable interest for both methodological and computational reasons. First they treat stochastic limiting resources in a way analogous to stochastic net revenues and yields. This formulation, therefore, allows an entirely symmetric interpretation of quadratic programming problems and leads to a substantial reduction in computational effort when compared with other stochastic specifications. These savings are achieved because the proposed formulation does not require either additional constraints

---

Quirino Paris is an associate professor of agricultural economics at the University of California, Davis.

Giannini Foundation Paper No. 519.

The author wishes to acknowledge helpful comments by R. Pope, P. L. Scandizzo, P. R. B. Hazell, J. R. Anderson, J. L. Dillon, J. B. Hardaker, P. Barry, and an anonymous referee, who must not be considered responsible for any remaining errors.

or variables over and above those involved in the traditional E-V approach when uncertainty is confined to only revenues and yields.

The first stochastic structure presented in this paper is based upon a methodological improvement of quadratic programming that occurred in 1963. (During the sixties, Cottle presented the same symmetric QP specification in at least five different papers.) In 1963, Cottle presented the symmetric version of quadratic programming. Although he discussed it from a purely formal point of view and did not suggest any empirical use of the new specification, it is one of considerable empirical potential. Furthermore, another unexplored but flexible programming structure, called the linear complementarity problem, will be shown to represent farm planning under uncertain revenues and costs (of limiting inputs) including interaction between the two components of profits.

Risky Revenues and Costs without Interaction

The setting is that of a farm whose entrepreneur operates in a competitive but uncertain environment. In general, uncertainty affects revenues in two ways: through output prices, **p**, and through yields. To keep the description to its maximum of simplicity, only output prices are considered aleatory. (One simple way to include stochastic yields into the framework was suggested by Hazell and Scandizzo.) The sources of uncertain costs we are especially interested in analyzing here are the supplies of "fixed" or limiting inputs, **s**, that is of those inputs which act as constraints on the production plan. As examples relevant to a farm environment, such aleatory supplies might be the amount of family labor determined by the number of days allowed by weather conditions, ground water for irrigation as determined by drought conditions, timing of custom operations as determined by the service availability, and machine availability as determined by the probability of repairs and losses. Uncertain prices and supplies of nonlimiting inputs are handled quite easily in the conventional E-V framework. With output activity levels indicated by the letter **x** and input (shadow) prices by the letter **y**, profits are simply $\pi = \mathbf{p}'\mathbf{x} - \mathbf{s}'\mathbf{y} = \mathbf{d}'\mathbf{z}$, where, by obvious correspondence, $\mathbf{d}' \equiv [\mathbf{p}', -\mathbf{s}']$ and $\mathbf{z}' \equiv [\mathbf{x}', \mathbf{y}']$; the dimensions of both **d** and **z** are taken to be $[(n + m)x1]$. Under these assumptions, only the **d** vector is stochastic. To adopt the E-V method, it is convenient to assume also that the **d** vector is normally distributed as $\mathbf{d} \sim N(E(\mathbf{d}), \Sigma)$, where $\Sigma = \begin{bmatrix} \Sigma_p & 0 \\ 0 & \Sigma_s \end{bmatrix}$. In turn, profits also will be normally distributed as $\pi \sim N(E(\pi), \mathbf{z}'\Sigma\mathbf{z}) = N(E(\mathbf{p})'\mathbf{x} - E(\mathbf{s})'\mathbf{y}, \mathbf{x}'\Sigma_p\mathbf{x} + \mathbf{y}'\Sigma_s\mathbf{y})$, since by assumption there is no interaction between output prices and input supplies.

The dual pair of symmetric quadratic problems describing the uncertain problems of the firm can now be stated as follows:

$$(1)\quad \text{Primal}\quad \max\{E(\mathbf{p})'\mathbf{x} - (\phi/2)\mathbf{x}'\Sigma_p\mathbf{x} - (\phi/2)\mathbf{y}'\Sigma_s\mathbf{y}\}$$
$$\text{subject to}\quad A\mathbf{x} - \phi\Sigma_s\mathbf{y} \leq E(\mathbf{s}),\quad \mathbf{y} \geq 0,\ \mathbf{x} \geq 0;$$

$$(2)\quad \text{Dual}\quad \min\{E(\mathbf{s})'\mathbf{y} + (\phi/2)\mathbf{y}'\Sigma_s\mathbf{y} + (\phi/2)\mathbf{x}'\Sigma_p\mathbf{x}\}$$
$$\text{subject to}\quad A'\mathbf{y} + \phi\Sigma_p\mathbf{x} \geq E(\mathbf{p}),\quad \mathbf{y} \geq 0,\ \mathbf{x} \geq 0.$$

The matrix A, of dimensions (mxn), represents the nonstochastic technology of the firm. The reason for referring to problems (1) and (2) as "symmetric" ought to be clear. Each relation of either problem exhibits the same formal structure as the corresponding dual relation. If the variance matrix of input supplies, Σ_s, is the null matrix, the dual pair (1) and (2) reduces to the familiar asymmetric quadratic programming commonly used to analyze the revenue uncertainty in the conventional E-V method.

The unusual and interesting property of the above model is that, if a solution exists, the vector variable **y** appearing in the primal problem represents also the vector of dual variables. To show this, it is sufficient to define the Lagrangean function of problem (1) using **y** as the vector of Lagrange multipliers, and verify that the resulting Kuhn-Tucker conditions are indeed identical to the constraints of problems (1) and (2). Hence, from the following Lagrangean function,

$$(3)\quad L = E(\mathbf{p})'\mathbf{x} - (\phi/2)\mathbf{x}'\Sigma_p\mathbf{x} - (\phi/2)\mathbf{y}'\Sigma_s\mathbf{y} + \mathbf{y}'[E(\mathbf{s}) + \phi\Sigma_s\mathbf{y} - A\mathbf{x}],$$

the Kuhn-Tucker conditions are $\mathbf{y} \geq 0$, $\mathbf{x} \geq 0$, and

$$(4)\quad \frac{\partial L}{\partial \mathbf{x}} = E(\mathbf{p}) - \phi\Sigma_p\mathbf{x} - A'\mathbf{y} \leq 0,$$

$$(5)\quad \mathbf{x}'\frac{\partial L}{\partial \mathbf{x}} = \mathbf{x}'E(\mathbf{p}) - \phi\mathbf{x}'\Sigma_p\mathbf{x} - \mathbf{x}'A'\mathbf{y} = 0,$$

$$(6)\quad \frac{\partial L}{\partial \mathbf{y}} = E(\mathbf{s}) + \phi\Sigma_s\mathbf{y} - A\mathbf{x} \geq 0, \text{ and}$$

$$(7)\quad \mathbf{y}'\frac{\partial L}{\partial \mathbf{y}} = \mathbf{y}'E(\mathbf{s}) + \phi\mathbf{y}'\Sigma_s\mathbf{y} - \mathbf{y}'A\mathbf{x} = 0.$$

Clearly, the systems of constraints (4) and (6) are identical to those in problems (2) and (1), respectively.

The economic interpretation of problems (1) and (2) can be based upon the conventional specification of E-V programming and on a novel reinterpretation of the constraints in terms of chance constrained programming.[1] According to the first scheme, the primal objective function requires the maximization of the firm's expected net revenue minus the risk premium that a risk-averse entrepreneur may be willing to pay for a certain level of monetary receipts. The risk premium is composed of two elements reflecting the double source of uncertainty: $(\phi/2)\mathbf{x}'\Sigma_p\mathbf{x}$ is the subjective cost the entrepreneur is willing to pay as a consequence of uncertainty in output prices; $(\phi/2)\mathbf{y}'\Sigma_s\mathbf{y}$ is the analogous cost associated with the uncertain input supplies.

The primal constraints represent the technological possibilities of the firm under a risky environment. When restated as $A\mathbf{x} \leq E(\mathbf{s}) + \phi\Sigma_s\mathbf{y}$ they clearly indicate the requirement that the input use, $A\mathbf{x}$, must be less than or equal to expected supplies $E(\mathbf{s})$, modified by a term $\phi\Sigma_s\mathbf{y}$, which constitutes a marginal risk adjustment directly related to the existence of uncertain input supplies. In general, nothing can be affirmed regarding the sign of this term, implying that risky conditions and risk aversion may dictate either a larger or a smaller procurement of inputs.

The performance function of the dual problem (2) can be viewed conveniently as the objective of an alternative entrepreneur who wishes to buy out the original owner. In this case, the new entrepreneur's goal is to minimize the total expected cost of the firm's aleatory input supplies, $E(\mathbf{s})'\mathbf{y}$, as well as the amount of money that he should reimburse the original owner for the payment of the risk premium.

The dual constraints of (2) are more familiar and correspond to the traditional E-V analysis. They can be rewritten as $A'\mathbf{y} \geq E(\mathbf{p}) - \phi\Sigma_p\mathbf{x}$, indicating that an equilibrium solution is reached when the marginal activity cost, $A'\mathbf{y}$, is greater than or equal to expected price, $E(\mathbf{p})$, adjusted by a marginal risk premium due to uncertain output prices.

The stochastic programming interpretation of problems (1) and (2) further supports the use of these structures for dealing with uncertain economic problems. In particular, it fully justifies the adoption of expected supplies $E(\mathbf{s})$ and the presence of the covariance matrix Σ_s of input supplies in the primal constraints. Suppose in fact that the entrepreneur's maximization of (1) is subject to the following chance constraint

$$(8)\qquad \text{Prob}\,(\mathbf{y}'A\mathbf{x} - \mathbf{y}'\mathbf{s} \leq 0) \geq \alpha,$$

where the input supplies $\mathbf{s}$ are random variables distributed as $\mathbf{s} \sim N(E(\mathbf{s}), \Sigma_s)$. The probability statement indicates that the imputed cost of factor use, $\mathbf{y}'A\mathbf{x}$, must be less than or equal to the inputed value of available resources with at least an α probability. In the terminology of stochastic programming, the probability α is referred to as a confidence level, while its counterpart $(1 - \alpha)$ is called risk level. It is postulated that the entrepreneur, confronted by a risky environment, chooses risk levels acceptable to him. In other words, the risk levels are related to his disliking (or preference) for risk: the smaller $(1 - \alpha)$, the smaller the propensity for risk taking of the entrepreneur. From the theory of chance-constrained programming (Vajda, p. 78), it can be shown that

$$\begin{aligned}(9)\quad \alpha &= \text{Prob}\,[\mathbf{y}'A\mathbf{x} - \mathbf{s}'\mathbf{y} \leq 0],\\ &= \text{Prob}\,[(-\mathbf{s}'\mathbf{x} + E(\mathbf{s})'\mathbf{y})/(\mathbf{y}'\Sigma_s\mathbf{y})^{1/2} \leq \tau_s],\\ &= \text{Prob}\,[E(\mathbf{s})'\mathbf{y} - \tau_s(\mathbf{y}'\Sigma_s\mathbf{y})^{1/2} \leq \mathbf{s}'\mathbf{y}].\end{aligned}$$

The choice of τ_s is made to satisfy $(1 - \alpha) = (1/\sqrt{2\pi})\int_{-\infty}^{\tau_s}\exp[-(1/2)w^2]dw$, where w is a standardized normal variate. When $\alpha > 1/2$, $\tau_s < 0$. Quoting Vajda (p. 80), "If $\mathbf{y}'A\mathbf{x}$ is not larger than $E(\mathbf{s})'\mathbf{y} - \tau_s(\mathbf{y}'\Sigma_s\mathbf{y})^{1/2}$, then it is not larger than any of those $s'\mathbf{y}$ which are not smaller than $E(\mathbf{s})'\mathbf{y} - \tau_s(\mathbf{y}'\Sigma_s\mathbf{y})^{1/2}$, and the

[1] At first sight it might seem natural to interpret the primal problem in terms of penalty cost programming, but this viewpoint is misleading for several reasons. First of all, penalty cost programming presupposes that decisions in the face of uncertainty are made in two stages: the first decision occurs prior to the eventuating of the uncertain outcome (input supplies) when a level $\bar{\mathbf{x}}$, of activities $\mathbf{x}$ is chosen; the second decision, concerning an adjustment between the realized input supplies, $\bar{\mathbf{s}}$, and the prior decision, $A\bar{\mathbf{x}}$, is permissible only at a cost. This structure requires the equality of primal constraints and, eventually, the knowledge of the realized input supplies, $\bar{\mathbf{s}}$. None of these conditions are present in the above formulation where all decisions are made without the exact knowledge of the eventuating outcome.

probability of such $\mathbf{s}'\mathbf{y}$ is α. Hence, the constraint Prob $[\mathbf{y}'A\mathbf{x} - \mathbf{s}'\mathbf{y} \leq 0] \geq \alpha$ is equivalent to the nonstochastic constraint

$$(10) \quad \mathbf{y}'A\mathbf{x} \leq E(\mathbf{s})'\mathbf{y} - \tau_s(\mathbf{y}'\Sigma_s\mathbf{y})^{1/2}."$$

The relationship between (10) and the primal constraints of problem (1) is established via the Kuhn-Tucker condition associated with (1) and given in (7). Hence, $\phi \leq -\tau_s/(\mathbf{y}'\Sigma_s\mathbf{y})^{1/2}$. If the E-V problem (1) is solved first, the probability α of the associated chance-constrained program can be derived by computing the value of τ_s as $\tau_s = -\phi(\mathbf{y}'\Sigma_s\mathbf{y})^{1/2}$ and then reading α from a table of the standardized normal variate. Notice that since $(\mathbf{y}'\Sigma_s\mathbf{y})^{1/2}$ and ϕ are both positive (for a risk-averse entrepreneur), the parameter τ_s is negative and the probability α of satisfying constraint (8) is greater than .5.

It should be emphasized that the stochastic specification is offered here as a further justification for the structure of constraints (1) rather than as a computational framework. In fact, solving the chance-constrained problem directly requires the solution of the nonlinear constraint (10), a task not easily performed. Here, it is suggested to make explicit the relationship between the E-V approach and stochastic programming by first solving problem (1) for a given coefficient of risk aversion, ϕ, and then computing the risk level $(1 - \alpha)$ compatible with such a risk aversion. If this is done, the input use, $A\mathbf{x}$, is guaranteed to be feasible for all those input supply outcomes, $\mathbf{s}$, that will be greater than or equal to $E(\mathbf{s}) + \phi\Sigma_s\mathbf{y}$. Therefore, the economic-technological interpretation of the primal constraints (1) can be summarized as follows: an entrepreneur with constant risk aversion, ϕ, who faces uncertain supplies of limiting inputs (normally distributed), may choose to replace the unknown constraints ($A\mathbf{x} \leq$ random $\mathbf{s}$) with the structure $A\mathbf{x} \leq E(\mathbf{s}) + \phi\Sigma_s\mathbf{y}$, requiring the knowledge of the first two moments of the probability distributions of the input supplies. This problem possesses the stochastic programming interpretation given above.

By analogy, a chance-constrained programming representation is readily available also for the dual constraints of the E-V problem. The stochastic specification corresponding to constraints (2) is thus

$$(11) \quad \text{Prob}\,(\mathbf{p}'\mathbf{x} - \mathbf{y}'A\mathbf{x} \leq 0) \leq 1 - \beta,$$

where the output prices, $\mathbf{p}$, are distributed as $\mathbf{p} \sim N[E(\mathbf{p}),\Sigma_p]$. The economic interpretation is that an entrepreneur would accept events where total revenue, $\mathbf{p}'\mathbf{x}$, may be less than or equal to total imputed cost, $\mathbf{y}'A\mathbf{x}$, with a probability $(1 - \beta)$, or smaller. Repeating the logical process outlined above, choose τ_p such that

$$(12) \quad \begin{aligned} 1 - \beta &= \text{Prob}\,[(\mathbf{p}'\mathbf{x} - E(\mathbf{p})'\mathbf{x})/(\mathbf{x}'\Sigma_p\mathbf{x})^{1/2} \leq \tau_p] \\ &= \text{Prob}\,[\mathbf{p}'\mathbf{x} \leq E(\mathbf{p})'\mathbf{x} + \tau_p(\mathbf{x}'\Sigma_p\mathbf{x})^{1/2}]. \end{aligned}$$

Therefore, the stochastic constraint Prob$(\mathbf{p}'\mathbf{x} \leq \mathbf{y}'A\mathbf{x}) \leq (1 - \beta)$ is equivalent to the nonstochastic constraint

$$(13) \quad \mathbf{y}'A\mathbf{x} \geq E(\mathbf{p})'\mathbf{x} + \tau_p(\mathbf{x}'\Sigma_p\mathbf{x})^{1/2}.$$

Again, the relationship between (12) and constraint (2) of the E-V problem is obtained via the complementary slackness condition of problem (1) given by (5). It follows that $\phi \leq -\tau_p/(\mathbf{x}'\Sigma_p\mathbf{x})^{1/2}$.

Solving the Generalized E-V Problem

The solution of problem (1) may be attempted with standard QP packages based, for example, on the Frank-Wolf algorithm; but this procedure is inefficient because it requires treating the dual variables $\mathbf{y}$ as primal variables. The size of the problem, then, becomes $[(2m + n) \times (2m + n)]$ with the introduction of auxiliary dual variables, say $\mathbf{w}$, which in the end, will turn out to be equal to $\mathbf{y}$.

Fortunately, a more efficient algorithm developed by Lemke is available. This algorithm was proposed for solving the linear complementarity problem (LCP). Hence, to use this solution procedure it is necessary to restate problem (1) in the form of the LCP.

The linear complementarity problem is defined as follows: find vector $\mathbf{z}$ such that

$$(14) \quad \mathbf{q} - M\mathbf{z} \leq 0, \quad \mathbf{z} \geq 0, \text{ and}$$

$$(15) \quad \mathbf{z}'(\mathbf{q} - M\mathbf{z}) = 0,$$

where M is a square matrix of dimensions $[(m + n) \times (m + n)]$ and $\mathbf{q}$ is any real vector, $\mathbf{q} \subset R^{m+n}$. For positive semidefinite matrices M, Lemke's algorithm guarantees to find a solution (if it exists) of the LCP.

To transform problem (1) into the structure of (14) and (15), it is sufficient to notice that the Kuhn-Tucker conditions associated with it are necessary and sufficient for a global maximum because the covariance matrices Σ_p and Σ_s are positive semidefinite. Hence, the K-T

conditions (4) through (7) can be rearranged into the structure of (14) and (15) by making the following correspondence:

$$z = \begin{bmatrix} \mathbf{x} \\ \mathbf{y} \end{bmatrix}, \; \mathbf{q} = \begin{bmatrix} E(\mathbf{p}) \\ -E(\mathbf{s}) \end{bmatrix}, \; M = \begin{bmatrix} \phi\Sigma_p & A' \\ -A & \phi\Sigma_s \end{bmatrix}.$$

The matrix M is positive semidefinite for any matrix A.

Constant Risk Aversion Utility Functions and the Generalized E-V Approach

The traditional E-V model, as proposed originally by Freund, was associated with a class of utility functions exhibiting constant absolute risk aversion. The generalized E-V model presented here is related to the same class, via the expected utility hypothesis.

Following Freund, the entrepreneur is assigned a concave utility function conveniently specified as

$$(16) \quad U(\pi) = 1 - \exp(-\phi\pi), \quad \phi > 0,$$

where ϕ is a subjective and constant coefficient of risk aversion and π represents profits as defined above. The entrepreneur is assumed to choose those levels of inputs and outputs which maximize the expected utility of his profits; that is,

$$(17) \quad EU(\pi) = 1 - \exp(-\phi[E(\pi) - \frac{\phi}{2}\,\mathrm{VAR}(\pi)]),$$

with E indicating the expectation operator.

Maximizing this monotonically increasing function is equivalent to

$$(18) \quad \max \{E(\pi) - \frac{\phi}{2}\,\mathrm{VAR}(\pi)\}$$

$$= \max \{E(\mathbf{d})'\mathbf{z} - \frac{\phi}{2}\,\mathbf{z}'\Sigma\mathbf{z}\},$$

$$= \max \{E(\mathbf{p})'\mathbf{x} - E(\mathbf{s})'\mathbf{y} - \frac{\phi}{2}\,\mathbf{x}'\Sigma_p\mathbf{x} - \frac{\phi}{2}\,\mathbf{y}'\Sigma_s\mathbf{y}\}.$$

Problem (18) is paired to the problem

$$(19) \quad \min \{\frac{\phi}{2}\,\mathbf{x}'\Sigma_p\mathbf{x} + \frac{\phi}{2}\,\mathbf{y}'\Sigma_s\mathbf{y}\},$$

which is interpreted as the minimization of the risk premium the risk-averse entrepreneur would be willing to pay for the certainty of being guaranteed a level of satisfaction equivalent to the maximum utility of expected profits. In other words, the quantity (19) is the difference between $E[U(\pi^*)]$ and $U[E(\pi^*)]$ where π^* is the value of profits obtained from solving problems (1) and (2).

A Digression on the Coefficient of Risk Aversion

The only characterization of the parameter ϕ made so far is that, for a risk-averse entrepreneur, it is a positive constant and represents his subjective evaluation of the importance of uncertainty. Freund pointed to the difficulty of obtaining adequate estimates of this coefficient, simply because of its subjective nature. In his empirical work he adopted a value of ϕ equal to 1/1250, rushing to advise that "any chosen value is exceedingly difficult to defend" (p. 258). This opinion seems overly pessimistic. Recently, Wiens has proposed that an average estimate of the same coefficient may be obtained by using the dual constraints of the E-V method in association with market as well as actual farm information. He noticed that for those activities operated at positive levels, the corresponding constraints of type (4) are binding and, therefore, can be solved for the ϕ coefficient as

$$(20) \quad \phi_F = [E(\mathbf{p}_j) - \mathbf{a}'_j\mathbf{r}]/\Sigma_{pj}\mathbf{x}_F,$$

where $\mathbf{a}_j$ is the jth activity (assumed to be operated at positive level), $E(\mathbf{p}_j)$ is the jth expected output price, and Σ_{pj} is the jth row of the variance matrix Σ_p; $\mathbf{r}$ is the vector of market prices for the limiting inputs and $\mathbf{x}_F$ is the vector of actual levels of activities operated by the entrepreneur. The subjective information derived from the entrepreneur is entirely incorporated in the vector $\mathbf{x}_F$ of personal choices of activity levels carried out in the uncertain environment as perceived by him.

The suggestion of Wiens has some merit if the information about the individual activity levels is available; but it requires also that the estimated ϕ not be used in conjunction with the data it was estimated from, as Wiens did. To begin with, his exclusive reliance on the dual constraints for the estimation of the risk-aversion coefficient is incomplete. The same coefficient can be estimated from the primal constraints (2) corresponding to positive shadow prices of the limiting inputs. In this case, the following relation is obtained:

(21) $\phi_F = [\mathbf{a}'_i \mathbf{x}_F - E(\mathbf{s}_i)]/\Sigma_{si}\mathbf{r},$

where $\mathbf{a}'_i$ is the ith row of the technological matrix A, $\mathbf{s}_i$ is the ith input supply, Σ_{si} is the ith row of the variance matrix Σ_s; $\mathbf{r}$ and $\mathbf{x}_F$ are the same as in (20). This second, or better, primal way to estimate ϕ, either may reinforce the consistency of the estimates of ϕ obtained from (20) or it may generate an embarrassment of choice. Obviously, this is an empirical dilemma. In any event, the two relations (20) and (21) taken together constitute a rather stringent test of the consistency of the risk-averse entrepreneur. They contain, in fact, all the information necessary to make an optimal decision. If the estimates of ϕ obtained from them are consistent (that is, are almost the same), it should be concluded that the entrepreneur's actual choices of output levels are optimal and no need exists to perform further optimizations. In other words, the utilization of the estimated ϕ in the quadratic programming model (in conjunction with the same data used to compute ϕ) merely corresponds to a tautological exercise.[2] The assumption of constancy of ϕ implies that a meaningful use of it requires a variation in either the technological or economic environment.

The reinterpretation of the E-V model in terms of chance constrained programming offers an alternative—and perhaps, more interesting—way to determine the coefficient of risk aversion ϕ. Such measures would naturally be defined as

$$\phi_F = -\tau_F/(\mathbf{r}'\Sigma_s\mathbf{r})^{1/2}, \text{ and}$$

$$\phi_F = -\theta_F/(\mathbf{x}'_F\Sigma_p\mathbf{x}_F)^{1/2},$$

where $\mathbf{r}$ and $\mathbf{x}_F$ have the same meaning as above, while τ_F and θ_F are parameters chosen to correspond to the subjective levels of probabilities α and β set by the firm's entrepreneur as a requirement for the fulfillment of constraints (8) and (11), respectively. Notice that in the above measures, the problem of multiple estimates of ϕ encountered in Wiens' method is avoided. Furthermore, the direct implications of using a linear technology (usually defined by the researcher rather than by the entrepreneur) are also eliminated. The parameters τ_F and θ_F replace the specification of the technology as an information tradeoff. Thus, it may be easier to elicit information from the entrepreneur concerning acceptable (to him) risk levels $(1 - \alpha)$ and $(1 - \beta)$, rather than either a detailed description of his input-output technology or a direct estimate of ϕ.

Risky Revenues and Costs with Interaction

The assumption of zero covariance between revenues and costs was convenient for maintaining a certain degree of simplicity. It is not, however, empirically satisfactory. If it had to be maintained because of the structure of either the symmetric QP or of the LC problem, it would almost nullify the significance of both programming frameworks. All published papers dealing with either market or farm planning in an E-V context have always glossed over the subject. This is a consequence of the structure of traditional E-V analysis and asymmetric *QP* problem. Uncertain supplies of limiting inputs will presumably interact with aleatory yields, rendering farm decisions even more challenging. In this section, therefore, the environmental uncertainty is redefined to include nonzero covariances between revenues and costs. Specifically, the covariances involve output prices and input quantities. Thus, the relevant variance matrix is now specified as $\Sigma = \begin{bmatrix} \Sigma_p & -\Sigma_{ps} \\ -\Sigma_{sp} & \Sigma_s \end{bmatrix}$, where, as before $\mathbf{p}$ and $\mathbf{s}$ are output price and input supply subscripts, respectively. The procedure to incorporate the nonzero covariance matrix Σ_{ps} into the generalized E-V method is slightly different from that presented in the previous sections. It is convenient to consider the expected utility model first. Then, the bilinear form $\phi\mathbf{x}'\Sigma_{ps}\mathbf{y}$, involving the covariance matrix appears in both primal and dual objective functions corresponding to (18) and (19) above, as an additional component of risk premium. The crucial aspect of this more general description of uncertain economic environments is the way the new matrix Σ_{ps} enters the primal and dual constraints. The relevant problem in terms of the expected utility hypothesis [analogous to (18) above] is now

[2] Wiens concludes that "the risk aversion model accords quite well with the average behavior of sampled peasants. Primal solutions in general call for full diversification among the three crops in proportions close to those observed" (p. 633). This statement represents a clear illustration of the tautological use of the estimated ϕ. The discrepancy between actual and optimal activity allocations reported by Wiens is due, on one level, to the use of only the dual constraints in the estimation of ϕ (in other words, he did not utilize the available information on input supply $E(\mathbf{s})$; on the other, to the averaging performed on the sample information.

$$(22)\quad \max\,[E(\pi) - \frac{\phi}{2}\,\mathrm{VAR}(\pi)]$$
$$= \max\,\{E(\mathbf{d})'\mathbf{z} - \frac{\phi}{2}\,\mathbf{z}'\Sigma\mathbf{z}\}$$
$$= \max\,\{E(\mathbf{p})'\mathbf{x} - E(\mathbf{s})'\mathbf{y} - \frac{\phi}{2}\,\mathbf{x}'\Sigma_p\mathbf{x} - \frac{\phi}{2}\,\mathbf{y}'\Sigma_s\mathbf{y} + \phi\mathbf{x}'\Sigma_{ps}\mathbf{y}\}.$$

Relation (22) remains a concave function because $\mathbf{z}'\Sigma\mathbf{z}$ is a positive semidefinite quadratic form. The dual to problem (22) [analogous to (19)] is

$$(23)\quad \min\,\{(\phi/2)\mathbf{x}'\Sigma_p\mathbf{x} + (\phi/2)\mathbf{y}'\Sigma_s\mathbf{y} - \phi\mathbf{x}'\Sigma_{ps}\mathbf{y}\}.$$

As before, (23) is to be interpreted as the minimization of the risk premium corresponding to this more complex environment. The linear complementarity problem which provides the structure for computing the more elaborate profit of (22) is finding $\mathbf{x} \geq 0$, $\mathbf{y} \geq 0$ such that:

$$(24)\quad A\mathbf{x} + \phi\Sigma_{sp}\mathbf{x} - \phi\Sigma_s\mathbf{y} \leq E(\mathbf{s}),$$

$$(25)\quad A'\mathbf{y} - \phi\Sigma_{ps}\mathbf{y} + \phi\Sigma_p\mathbf{x} \geq E(\mathbf{p}),$$

$$(26)\quad \mathbf{y}'[A\mathbf{x} + \phi\Sigma_{sp}\mathbf{x} - \phi\Sigma_s\mathbf{y} - E(\mathbf{s})] = 0,$$

and

$$(27)\quad \mathbf{x}'[A'\mathbf{y} - \phi\Sigma_{ps}\mathbf{y} + \phi\Sigma_p\mathbf{x} - E(\mathbf{p})] = 0.$$

In this case, the matrix M of the new LCP is $M = \begin{bmatrix} \phi\Sigma_p & A' - \phi\Sigma_{ps} \\ -A - \phi\Sigma_{sp} & \phi\Sigma_s \end{bmatrix}$. The difference between this set of restrictions and those presented in (4) through (7) is that the covariance term Σ_{sp} appears explicitly either to impose further restrictions on the input use, or to relax their binding availabilities, depending upon the sign of the term $\Sigma_{sp}\mathbf{x}$. In a perhaps more illustrative expression, constraints (24) may be restated as $A\mathbf{x} + \phi\Sigma_{sp}\mathbf{x} \leq E(\mathbf{s}) + \phi\Sigma_s\mathbf{y}$. The left-hand side indicates that the input use $A\mathbf{x}$, must now be properly adjusted to account for the interaction between output prices and input quantities. It should be transparent that, in general, the level of output, $\mathbf{x}$, admissable by the system of constraints will be either larger or smaller than that corresponding to $\Sigma_{ps} = 0$, depending upon the sign of $\Sigma_{sp}\mathbf{x}$. In a similar restatement of constraints (25), $A'\mathbf{y} - \phi\Sigma_{ps}\mathbf{y} \geq E(\mathbf{p}) - \phi\Sigma_p\mathbf{x}$, the marginal activity cost must be adjusted by the marginal risk factor $\phi\Sigma_{ps}\mathbf{y}$, depending exclusively upon the nonnegligible interrelation between input supplies and output prices. The right hand side is, again, unchanged.

The check of consistency of the risk-averse entrepreneur according to Wiens' suggestion becomes even more formidable than in the previous case. As before, for binding primal constraints and positive output activity levels, it is possible to compute the risk-aversion coefficient of the individual entrepreneur in two quite different but strictly related ways: from (24) and the ith (assumed) binding constraint the following is obtained

$$(28)\quad \phi_F = [\mathbf{a}'_i\mathbf{x}_F - E(\mathbf{s}_i)]/(\Sigma_{si}\mathbf{r} - \Sigma_{spi}\mathbf{x}_F).$$

Similarly, from (25) and the jth (assumed) positive activity level:

$$(29)\quad \phi_F = [E(\mathbf{p}_j) - \mathbf{a}'_j\mathbf{r}]/(\Sigma_{pj}\mathbf{x}_F - \Sigma_{psj}\mathbf{r}),$$

where $\mathbf{r}$ and $\mathbf{x}_F$ have the meaning already established. Caution ought to be exercised in the use and interpretation of these relations. Failure to obtain close values of ϕ from the two formulas should not be immediately considered as an inconsistency of the entrepreneur; it may be due to the particular technological matrix, A, chosen by the researcher.

Notice that introduction of nonzero covariances between input quantities and output prices prevents the restatement of problem (22) in the form of symmetric quadratic programming. It does not prevent, however, its transformation into a corresponding linear complementarity problem. The matrix M remains a positive semidefinite matrix since $\mathbf{z}'M\mathbf{z} = \phi\mathbf{z}'\Sigma\mathbf{z} \geq 0$, for any $\mathbf{z}$. Hence, Lemke's algorithm is guaranteed to find a solution to the LC problem, if one exists.

Empirical Issues and Conclusions

The analysis presented above was focused entirely on methodological issues. The empirical implementation of any of the models, however, was always kept in mind. Indeed, this is the main reason for dealing with uncertain environments within an E-V framework rather than with more flexible but more demanding approaches. The inevitable question, therefore, looms on the horizon: how can the variance of input supplies be estimated? One would feel tempted to reply: in the same way

the variances of either output prices or yields are computed. Upon further reflection, though, it must be admitted that, typically, data collectors pay disproportionately large attention to the revenue side of the economy with the cost aspect remaining underdeveloped. The question is legitimate, therefore, although only a few hints can be offered to alleviate the informational imbalance. It may be hoped that once models of cost uncertainty are developed in large numbers, the need for accurate and suitable cost information also will become evident to the data-gathering bureaucracies. In the meantime, one must use ingenious devices such as Boisvert and Jenson's idea for estimating the variance of family labor on small Minnesota farms. They suggest that the expected field days of the farm family and their variance will be computed from records of monthly weather information. Another suggestion deals with water. With drought having affected various parts of the country in recent years, an analogous method can be perfected for estimating means and variances of available water supplies. At the aggregate level—not discussed in this note—other appropriate suggestions can be formulated for the variances of, say, energy, labor supply, financial capital, and so on. One thing ought to be emphasized. The initial lack of empirical procedures should not deter any researcher from developing and presenting unusual but more realistic models.

The great surprise of this development is the realization that either quadratic programming or the linear complementarity problems are suitable structures to deal with rather complex problems. Their flexibility to handle a variety of meaningful economic problems barely has been tapped by the treatment presented in this note. I would expect that many other and more meaningful uses of both symmetric QP and LC problems are awaiting to be dusted from the shelves of intellectual neglect.

[*Received March 1978; revision accepted October 1978.*]

References

Boisvert, R. N., and H. R. Jenson. "A Method for Farm Planning under Uncertain Weather Conditions with Applications to Corn-Soybean Farming in Southern Minnesota." Minnesota Agr. Exp. Sta. Tech. Bull. 292, 1973.

Camm, B. M. "Risk in Vegetable Production on a Fen Farm." *Farm Economist* 10(1963):89–98.

Charnes, A., and W. W. Cooper. "Chance Constrained Programming." *Manage. Sci.* 6(1959):73–79.

Cocks, K. D. "Discrete Stochastic Programming." *Manage. Sci.* 15(1968):72–79.

Cottle, R. W. "Symmetric Dual Quadratic Programs." *Quart. Appl. Math.* 21(1963):237–42.

Dantzig, G. B., and A. Madansky. "On the Solution of Two-Stage Linear Programs Under Uncertainty." Fourth Berkeley Symposium on Math. Stat. and Prob. 1(1961):165–76, University of California Press.

Freund, R. J. "The Introduction of Risk into a Programming Model." *Econometrica*, 24(1956):253–63.

Hazell, P. B. R., and R. B. How. "Obtaining Acceptable Farm Plans Under Uncertainty." *Policies, Planning and Management for Agricultural Development.* Papers and Reports of the 14th International Conference of Agricultural Economists (1971):338–47.

Hazell, P. B. R., and P. L. Scandizzo. "Competitive Demand Structures under Risk in Agricultural Linear-Programming Models." *Amer. J. Agr. Econ.* 56(1974):235–44.

Lemke, C. E. "Bimatrix Equilibrium Points and Mathematical Programming." *Manage. Sci.* 11(1965):681–89.

McFarquar, A. M. J. "Rational Decisions-Making and Risk in Farm Planning." *J. Agr. Econ.* 14(1961): 552–63.

Maruyama, Y. "A Truncated Maximin Approach to Farm Planning under Uncertainty with Discrete Probability Distributions." *Amer. J. Agr. Econ.* 54(1972):192–200.

Rae, A. N. "Stochastic Programming, Utility, and Sequential Decision Problems in Farm Management." *Amer. J. Agr. Econ.* 53(1971):448–60.

Tintner, G. "Stochastic Linear Programming with Applications to Agricultural Economics." *Proc. 2nd Symp. Linear Programming* 1(1955):197–228.

Vajda, S. *Probabilistic Programming,* New York: Academic Press, 1972.

Wiens, T. B. "Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment." *Amer. J. Agr. Econ.* 58(1976):629–35.

Production Function Estimation and Related Risk Considerations

Richard E. Just and Rulon D. Pope

There has been considerable interest in estimations of input effects on the probability distribution of output. Most empirical and theoretical analyses utilize multiplicative stochastic specifications which are analyzed and found unduly restrictive, particularly since inputs that marginally reduce risk are not allowed. A more general stochastic specification is proposed, free of these a priori restrictions. The proposed functional form estimation is discussed and demonstrated with nitrogen-response data and common log-linear production functions. Though nitrogen is risk-increasing, the marginal variance contribution is smaller when compared to estimates based upon multiplicative specification. Finally, stochastic specification error effects are analyzed.

Key words: fertilizer response functions, production functions, risk.

Increasingly, risk considerations are necessary in the analysis of the agricultural sector. Risk is affected not only by price and other market-related phenomena but also by many technological innovations and government policies related to input use. For example, much of the controversy surrounding pesticide regulations relates to their reducing risk (see Turpin and Maxwell). In such a case, intelligent public policy formulation should consider not only the marginal contribution of pesticide use to the mean of output but also the marginal reduction in variance of output. Other examples in which increased input use appears to reduce variability are "overcapitalization," frost protection such as use of smudge pots, and possibly irrigation. Consider, for example, overcapitalization in grain harvesting. The use of large (and fast) harvesting equipment, as opposed to smaller (and slower) equipment, usually leads to less variability of output (because of random weather conditions which can destroy a ripe crop before harvest).

The problem of investigating stochastic aspects of production response is apparently an old one (Fuller, Day, and Anderson). The traditional approach in agricultural economics to evaluating the impact of inputs on risk in production has been to use experimental data. This method, of course, allows the variance of yields to be estimated within cells. A number of other authors (e.g., de Janvry and Fuller) have recognized that more efficient estimation is possible by utilizing continuous response functions. Apparently thus far, however, no one has given adequate attention to the effect of inputs on risk. This is true of both empirical and theoretical studies. As shown in this paper, virtually all empirical and theoretical studies make implicit, if not explicit, assumptions to the effect that inputs increase risk. Examples of such theoretical studies are such notable works as Stiglitz, Batra, Magnusson, Crawford, Rothenberg and Smith, Bardhan, and Feldstein. Examples of empirical works include such notables as de Janvry, Wolgin, Sadan, and Moscardi and de Janvry.

The purpose of this paper is to examine the implications of traditional econometric production function studies when the above issues are important and, then, to demonstrate some useful generalizations. Attention will be focused on neoclassical log-linear production functions. First, the restrictions associated with popular formulations of stochastic production functions are developed. A more generalized stochastic specification for production function estimation is then posed, and its generality in reflecting the risk effects of input use is demonstrated. The functional form proposed is general enough to encompass the deterministic implications of all the functions used in the above studies but avoids the risk-related restrictions they impose. A methodol-

Richard E. Just is an associate professor of agricultural and resource economics, University of California, Berkeley, and Rulon D. Pope is an assistant professor of agricultural economics, University of California, Davis.

ogy for estimating the generalized specification is discussed. Finally, application of the methodology is exemplified with the well-known fertilizer response data used in a previous study by Day.

Shortcomings of Popular Production Specifications

Historically, a popular enconometric specification in production function estimation has been

$$(1)\qquad y = A\left(\prod_{i=1}^{n} X_i^{\alpha_i}\right)e^{\epsilon},$$

where y is output, X_i is a factor input ($X_i > 0$), and ϵ is a stochastic disturbance with $E(\epsilon) = 0$, $V(\epsilon) > 0$.

Consider the marginal effect of input use on production variability. One finds that

$$V(y) = A^2\left(\prod_{i=1}^{n} X_i^{2\alpha_i}\right)V(e^{\epsilon}),$$

and, hence, that

$$(2)\qquad \frac{\partial V(y)}{\partial X_i} = \frac{2\alpha_i A^2}{X_i}\left(\prod_{i=1}^{n} X_i^{2\alpha_i}\right)V(e^{\epsilon}) > 0,$$

assuming $\alpha_i > 0$. Thus, the marginal effect of increasing input use must always be to increase the variability of output when the relevant $\alpha_i > 0$; and α_i must be positive if marginal productivity is positive.

Pragmatically, the implications of using the usual formulation in (1) are as follows. Consider the evaluation of a policy which limits the use of some input such as pesticides. Using (1), a reduction in pesticide use would imply by (2) a reduction in variability of output. In reality, however, a reduction in pesticide use may lead to more variable production. Under risk aversion, the true utility loss associated with higher risk (at the lower input level) will be greater than when the risk effect is incorrectly estimated as a reduction in variability [as implied by (1)].[1] Similarly, if one were to promote the expansion of irrigated acreage and thereby reduce risk, the estimated benefits (again assuming risk aversion) would be greater than when the reduction in risk is ignored or is incorrectly estimated as an increase in risk as suggested by (1) and (2). Incorrect conclusions of this type also can be obtained in evaluation of policies which affect inputs that increase risk because of the lack of flexibility in (1).

Consider, further, the marginal effect of input use on marginal productivity variability. Here one finds

$$\frac{\partial y}{\partial X_i} = \frac{\alpha_i y}{X_i},$$

$$V\left(\frac{\partial y}{\partial X_i}\right) = \frac{\alpha_i^2}{X_i^2}V(y),$$

$$\frac{\partial V(\partial y/\partial X_i)}{\partial X_i} = -(1-\alpha_i)$$

$$\cdot\ \frac{2\alpha_i^2 A^2}{X_i^3}\left(\prod_{i=1}^{n} X_i^{2\alpha_i}\right)V(e^{\epsilon}) < 0,$$

assuming $\alpha_i < 1$ or equivalently that $E(y)$ is concave in X_i. Thus, the marginal effect of increasing input use is always to reduce the variability of the marginal product (unless expected production is not concave in X).

It appears, however, that in many realistic situations this constraint may be overly restrictive. For example, it seems that in some cases the variability of the marginal productivity of land increases when other inputs are held fixed. As one farms on a more extensive basis with the same inputs, "fire fighting" ability is reduced (Radner and Rothschild). That is, one is more subject to adverse weather conditions, etc., during such critical operations as harvesting and planting. On the other hand, an input such as smudge pots in frost protection is likely to have a decreasing marginal productivity variability because survival of the crop becomes more probable, and marginal productivity presumably tends in probability toward zero with increased input use (in the relevant range).

Of course, many functional forms other than the Cobb-Douglas have been used econometrically in production-function estimation. Examples are the transcendental function (Halter, Carter, Hocking), the generalized power production function (de Janvry), and the translog function (Christensen, Jorgenson, Lau). However, all of these functions including Kmenta's approximation of the CES function are estimated in practice by specifying a log-linear disturbance: $y = f(X)e^{\epsilon}$, $E(\epsilon) = 0$, where $f(X)$ represents the particular functional

[1] Although it is well known that variance has limitations as a measure of risk (Borch), risk is associated with variance in the above discussion because $1/2\ \partial V(y)/\partial X_i = \text{cov}\,(y, \partial y/\partial X_i)$ and $\text{cov}\,(y, \partial y/\partial X_i)$ determines whether a risk averter uses more or less of the input X_i than the risk-neutral producer under production uncertainty (Horowitz).

form. And each of these cases has the same shortcomings discussed above for the Cobb-Douglas because

$$V(y) = f^2(X)V(e^{\epsilon}),$$

$$\frac{\partial V(y)}{\partial X_i} = 2f(X)f_i(X)V(e^{\epsilon}) > 0,$$

$$\frac{\partial y}{\partial X_i} = f_i(X)e^{\epsilon}, V\left(\frac{\partial y}{\partial X_i}\right) = f_i^2(X)V(e^{\epsilon}),$$

$$\frac{\partial V(\partial y/\partial X_i)}{\partial X_i} = 2f_i(X)f_{ii}(X)V(e^{\epsilon}) < 0,$$

when $f_i > 0$, $f_{ii} < 0$.

A Reasonable Stochastic Specification under Risk

The results of the previous section point to an important problem with the traditional stochastic specification of production functions. Namely, if any input has a positive effect on output, then a positive effect on variability of output is also imposed. The arguments of the previous section imply that the effects of input on output should not be tied to the effects of input on variability of output a priori. To attain this generality, it seems that an adequate production-function specification should include two general functions—one which specifies the effects of input on the mean of output and another which specifies the effects of input on the variance of output. Such a function is given by

(3) $y = f(X) + h^{1/2}(X)\epsilon,\ E(\epsilon) = 0,\ V(\epsilon) = 1.$

Thus, $E(y) = f(X)$, $V(y) = h(X)$, so that the effects on mean and variance of output can be independent. (For alternatives to this specification, see Just and Pope.)

With the specification in (3), one can easily verify that

$$\frac{\partial V(y)}{\partial X_i} = h_i(X)$$

(4) $$\frac{\partial y}{\partial X_i} = f_i(X) + \frac{1}{2}h^{-1/2}(X)h_i(X)\epsilon, \quad \text{and}$$

$$V\left(\frac{\partial y}{\partial X_i}\right) = \frac{h_i^2(X)}{4h(X)},$$

(5) $$\frac{\partial V(\partial y/\partial X_i)}{\partial X_i} = \frac{h_i(X)[h(X)h_{ii}(X) - h_i^2(X)]^2}{2h^2(X)}.$$

It can be affirmed readily that the signs of neither (4) nor (5) are determined a priori even when $h(X)$ follows one of the popular production function forms (Cobb-Douglas, translog, etc.) with parameters unconstrained. For example, if $h(X)$ follows a Cobb-Douglas form and the ith input is associated with a negative parameter, then $h_i(X) < 0$; and thus the case of a risk-reducing input is exemplified.

It is further interesting to note that the popular specification in (1) is simply a special case of (3). This is apparent because, regardless of specific functional forms,

$$y = f^*(X)e^{\epsilon^*} = f(X) + h^{1/2}(X)\epsilon,$$
$$E(\epsilon^*) = E(\epsilon) = 0$$

where $f(X) \equiv h^{1/2}(X) \equiv f^*(X)E(e^{\epsilon^*})$, and $\epsilon \equiv e^{\epsilon^*} - E(e^{\epsilon^*})$. Thus, the proposed functional form can be no more restrictive in any sense so long as explicit specifications admit the possibility that $f(X) = h^{1/2}(X)$.

An Estimation Procedure

For empirical purposes, suppose both f and h follow a popular log-linear form—Cobb-Douglas or translog (Christensen, Jorgenson, Lau; Just and Pope). Thus, $f(X) = h^{1/2}(X)$ is a potential special case. Estimation with log-linearity can be accomplished as follows. First, rewrite (3) for observation t explicitly including the parameters of f and h as

(6) $$y_t = f(X_t, \alpha) + \epsilon^*_t,$$
$$E(\epsilon^*_t) = 0,\ E(\epsilon^*_t\epsilon^*_\tau) = 0 \text{ for } t \neq \tau,$$

where $\epsilon^*_t = h^{1/2}(X_t, \beta)\epsilon_t$, $E(\epsilon_t) = 0$, $E(\epsilon_t\epsilon_\tau) = 0$ for $t \neq \tau$. One can then consider (6) as a nonlinear, heteroscedastic regression of y on X. It can be shown, following the methods of Malinvaud, that nonlinear least squares (NLS) applied to (6) leads to consistent estimators of α, the parameters of f, and of $f(X_t, \alpha)$ itself under a broad range of conditions (see Just and Pope).

If one is interested only in estimation of f, this may be as far as one needs to proceed. However, there are several important reasons for carrying the estimation procedure beyond this point. An obvious reason is to learn more about the effect of input use on risk. But even if risk is not important, there are several econometric shortcomings if one obtains only the above results. First, because of heteroscedasticity, hypothesis testing about the importance of various variables cannot generally be performed. But, secondly, by taking ac-

count of the heteroscedasticity, it is possible to gain more efficiency in estimation (at least asymptotically).

To accomplish this, one can consider two additional stages of estimation. Using the (consistent) estimate of α, say, $\hat{\alpha}$, one can consistently estimate $f(X_t, \alpha)$ by $f(X_t, \hat{\alpha})$ and, thus, ϵ^*_t or $h^{1/2}(X_t, \beta)\, \epsilon_t$ can be estimated by

$$\hat{\epsilon}^*_t = y - f(X_t, \hat{\alpha}),$$

under a broad range of conditions. But note that

$$E[(\epsilon^*_t)^2] = E[h(X_t, \beta)\epsilon_t^2] = h(X_t, \beta).$$

Recalling the work of Hildreth and Houck and others on the random coefficient regression problem (see Theil), this suggests a regression equation based on the relationship

$$(7) \qquad \begin{aligned}(\epsilon^*_t)^2 &= E[(\epsilon^*_t)^2]u_t \\ &= h(X_t, \beta)u_t,\end{aligned}$$

where $E(u_t) = 1$ by the definition of expectations. That is, β can be estimated by regressing $(\epsilon^*_t)^2$ on X_t (in a nonlinear framework) or, because $\hat{\epsilon}^*_t$ consistently estimates ϵ^*_t, regressing $(\hat{\epsilon}^*_t)^2$ on X_t leads to the same regression results asymptotically. Taking logarithms, this can be accomplished by ordinary least squares (OLS) regression of $ln|\hat{\epsilon}^*_t|$ on $ln\, X_t$ because (7) implies

$$(8) \qquad ln|\epsilon^*_t| = \beta_o + \frac{1}{2}(ln\, X_t)'\beta + u^*_t,$$

$$E(u^*_t) = 0$$

where $\beta_o = E(ln\, u_t)$, $u^*_t = ln\, u_t - E(ln\, u_t)$,[2] and

$$(9) \qquad ln\, h(X_t, \beta) = (ln\, X_t)'\beta.$$

Furthermore, OLS yields a consistent estimator for β under the same conditions required for consistency in the first-stage NLS problem.

Given consistent estimation of β in the regression problem in (8), it is possible to compute a nonlinear generalized least-squares estimator for the regression in equation (6) in essentially the same way as proposed by Zellner and Hildreth and Houck. Where $\hat{\beta}$ is the estimator obtained above, one obtains a consistent estimator $h(X_t, \hat{\beta})$ for the variance of ϵ^*_t (with the above functional form and conditions developed by Christensen, Jorgenson, Lau; and Just and Pope).[3] Hence, a weighted NLS regression of y_t on X_t in (6) with weights $h^{-1/2}(X_t, \hat{\beta})$ can attain asymptotic efficiency in estimation of α. In other words, in a third stage one would find an NLS estimate of α for the model

$$y^*_t = f^*(X_t, \alpha) + \tilde{\epsilon}_t,$$

where

$$y^*_t = y_t h^{-1/2}(X_t, \hat{\beta}),$$
$$f^*(X_t, \alpha) = f(X_t, \alpha)h^{-1/2}(X_t, \hat{\beta}).$$

It has been rigorously shown elsewhere by Just and Pope that the estimator for α thus obtained is consistent, asymptotically efficient, and unbiased under conditions indicated above so long as fourth moments of ϵ_t exist when the regression equation in (7) is used directly.

In summary, the regression method thus involves the following steps:

(*a*) An NLS regression of y_t on $f(X_t, \alpha) = \exp\,[(ln\, X_t)\alpha]$ obtaining, say, $\hat{\alpha}$.

(*b*) An OLS regression of $ln|\hat{\epsilon}^*_t| = ln|y_t - f(X_t, \hat{\alpha})|$ on $ln\, X_t$ obtaining, say, $\hat{\beta}$.

(*c*) An NLS regression of $y^*_t = y_t h^{-1/2}(X_t, \hat{\beta}) = y_t \exp\left[-\frac{1}{2}(ln\, X_t)'\hat{\beta}\right]$ on $f^*(X_t, \alpha) = \exp\left[(ln\, X_t)'\alpha - \frac{1}{2}(ln\, X_t)'\hat{\beta}\right]$ obtaining, say, $\hat{\alpha}$.

Production Function Estimation with Experimental Data

The steps of estimation in (*a*), (*b*), and (*c*) require some modification when data are generated experimentally by a cross-section of time series where perhaps the same random phenomena, such as weather, affect all contemporaneous observations.[4] The investigation of data with time or cross-section effects has been discussed extensively in the literature on variance components (e.g., Hoch; Wallace and Hussain). A general conclusion is

[2] Note that β_o is defined to take account of the nonzero expectation of $ln|\epsilon^*_t|$. This modification is required to obtain consistency in estimation of β using the linear regression equation in (8). For a proof of the consistency of this approach, see Just and Pope. Kelejian uses a similar approach.

[3] One can also note in this case that a negative estimate of the variance of ϵ^*_t will not result as in the Hildreth and Houck treatment of random coefficient regression because of the log-linear specification of h.

[4] Alternatively or additionally, one similarly could consider plot effects across years. The possibility of plot or cell-associated random terms, however, will not be discussed explicitly in this paper since they are not necessary in the empirical cases considered explicitly; furthermore, the necessary generalizations follow simply from the discussion in this paper. A further generalization of the model could also be developed by considering random coefficients as proposed by Hildreth and Houck and Feldstein.

that time effects can be investigated either by using dummy variables representing different time periods or by using a variance components procedure. However, Maddala has shown that the variance components approach is an efficient way of combining the information obtained from using dummy time variables with that from using least squares without dummies. Furthermore, Wallace and Hussain show that asymptotic efficiency is attained only with the variance components approach when the regressors repeat from time period to time period as they do with the data used here. Although these results were derived under linearity, it is clear that similar results would hold in the model considered in this paper if any dummy terms are included additively.

To obtain a variance components modification of the estimation procedure outlined above, equation (3) can be augmented by adding an error term w_t, as well as time and plot subscripts t and i, to existing variables in the equation. The model thus becomes

$$(10) \qquad y_{ti} = f(X_{ti}, \alpha) + h^{1/2}(X_{ti}, \beta)(\epsilon_{ti} + w_t),$$

with $E(\epsilon_{ti}) = 0$; $E(w_t) = 0$, $E(\epsilon_{ti}\epsilon_{\tau j}) = \delta_{t\tau}\delta_{ij}$, $E(w_t w_\tau) = \delta_{t\tau}\sigma$, $E(\epsilon_{ti} w_\tau) = 0$, and where σ is the variance of w_t and δ_{ij} is the Kronecker delta. A generalization of the estimation procedure in the previous section which attains consistency for this model is given in the appendix of this paper.

An Application in Fertilizer Response

To demonstrate the approach of this paper, the notable data set investigated by Day has been selected. Briefly, his yield data were generated for several crops by controlled experiments varying fertilization over several fixed levels. Observations were generated by recording time series of data over a cross-section of plots. Using these data, Day attempts to determine the distribution of yield at each level of fertilization among the family of Pearson-type distributions. His data are useful for exemplifying the methodology of this paper because problems of multicollinearity are not encountered and because concentration on a single input in investigating risk effects is possible.

Because the data possess both time-series and cross-section characteristics, the methodology of the previous section is applicable. Even though the data were generated with a cross-section of plots, however, it does not seem reasonable to specify a plot effect because the plots were in very close proximity of one another (a test against this specification was not possible because plot attributes were not recorded with the data). However, it is likely that time effects are important because different plots are affected by the same weather conditions each year.

The functional forms which are investigated are the Cobb-Douglas and the translog specifications. That is, in each case one set of estimates is obtained in which both f and h follow the Cobb-Douglas form,

$$(11) \qquad y_{ti} = AZ_{ti}^{\alpha_1} + BZ_{ti}^{\beta_1}(\epsilon_{ti} + w_t);$$

another is obtained where both f and h follow the translog specification:

$$(12) \qquad y_{ti} = AZ_{ti}^{\alpha_1} \exp\left\{\frac{1}{2}\alpha_2 \ln^2 Z_{ti}\right\} + BZ_{ti}^{\beta_1} \exp\left\{\frac{1}{2}\beta_2 \ln^2 Z_{ti}\right\}(\epsilon_{ti} + w_t).$$

Note that the above equations are both special cases of (9).

Following the estimation methodology of the previous section, the results are presented in tables 1, 2, and 3 for corn and oats. In each case the dependent variables are measured in bushels per acre, and the independent variable is pounds of nitrogen per acre (see Day for the data and a further description). Table 1 contains the ordinary nonlinear least-squares estimates of equation (A.4).[5] Table 2 contains

[5] The standard errors reported in parentheses in table 1 should thus be interpreted with caution because disturbances in (A.4) are not uniformly distributed under the assumptions in (A.1) and (A.2).

Table 1. First-Stage Estimates of the Deterministic Component of Production

Crop	Functional Form	Constant Term A	Fertilizer Coefficients[a] α_1	α_2
Corn	Cobb-Douglas	14.759 (2.195)	.3053 (.0445)	
Corn	Translog	20.916 (14.384)	.0634 (.4698)	.0806 (.1561)
Oats	Cobb-Douglas	10.900 (1.248)	.4195 (.0317)	
Oats	Translog	6.194 (2.597)	.8804 (.2356)	−.1568 (.0653)

Note: Figures in parentheses are standard errors, estimated under the assumption of homoscedasticity.
[a] See equations (11) and (12) for functional forms.

Table 2. Second-Stage Estimates of the Stochastic Component of Production

Crop	Functional Form	Constant Term β^*_0	Constant Term $\bar{\beta}_0$	Fertilizer Coefficients[a] β_1	Fertilizer Coefficients[a] β_2	Standard Error $\sigma = \frac{\bar{\beta}_0}{\beta^*_0 - \bar{\beta}_0}$
Corn	Cobb-Douglas	74.169	80.605	.1269		11.524
		(22.107)	(25.037)	(.0462)		
Corn	Translog	178.61	193.98	−.1852	.1058	11.621
		(251.48)	(273.21)	(.4908)	(.1653)	
Oats	Cobb-Douglas	42.272	57.428	.1999		2.789
		(12.686)	(17.708)	(.0395)		
Oats	Translog	5.879	7.489	.7846	−.1693	3.652
		(8.151)	(10.499)	(.3909)	(.1079)	

Note: Figures in parentheses are standard errors, estimated under the assumption of homoscedasticity in equation (8); see equation (8) for the interpretation of β^*_0 and $\bar{\beta}_0$.
[a] See equations (11) and (12) for functional forms.

the second-stage results corresponding to (A.2).[6] Table 3 presents the nonlinear generalized least-squares results corresponding to equation (A.4) with covariance matrix estimated on the basis of table 2.

Consistent with Fuller's findings, the results in table 2 imply that fertilizer has a positive marginal effect on yield variability in the relevant range. This result obviously holds for all positive fertilizer levels in the Cobb-Douglas formulations; for the translog cases, the marginal effect on corn yields is positive if the fertilization rate is greater than 5.757 pounds per acre, and the marginal effect on the oats' yield is positive if the fertilization rate is less than 102.964 pounds per acre (active nutrients). It is interesting that, with translog generality, the marginal effect on yield variability is increasing for corn but decreasing for oats.

Another notable result is that the elasticity for variability is much lower in each case than the elasticity for the mean of yield. For example, the α_1 estimates are considerably higher than the β_1 estimates in the Cobb-Douglas cases. This result has important implications for the applicability of the usual stochastic specification in production-function estimation, i.e., the one with log-linear disturbances. Consider the commonly used specification (dropping the variance components specification for convenience):

(13) $y_t = f(X_t)e^{\delta_t} = \tilde{A}X_t^{\alpha_1}e^{\delta_t},\ E(\delta_t) = 0.$

[6] The standard errors reported in table 2 are generated by ordinary nonlinear least squares. However, they may not apply exactly even in an asymptotic sense because the disturbances in (A.3) may not be uncorrelated or uniformly distributed.

Letting $A = \tilde{A}E(e^{\delta_t})$ and $\epsilon_t = e^{\delta_t} - E(e^{\delta_t})$, (13) can be rewritten as

$$y_t = AX_t^{\alpha_1} + BX_t^{\beta_1}\epsilon_t,\ E(\epsilon_t) = 0,$$

where

(14) $$B = \tilde{A} = A[E(e^{\delta_t})]^{-1},$$

(15) $$\beta_1 = \alpha_1.$$

Thus, the Cobb-Douglas case examined in this paper has a special case which includes the common specification in (13). If (13), in fact, holds, one expects to find, among other things, $\alpha_1 = \beta_1$; hence, the usual case is apparently not supported.[7] If one considers the above

[7] By orthogonality of regression residuals to coefficient estimates in the first stage, the distribution of coefficients in the second stage is independent of that for the first stage. A test of equality of coefficients (other than the constant term) in the first two stages, based on this fact and the usual least squares statistics, leads to rejection of equality at the 2.5% level. Unfortunately, however, least squares statistics are not applicable, so limited confidence can be placed in the test.

Table 3. Third-Stage Estimates of the Deterministic Component of Production

Crop	Functional Form	Constant Term A	Fertilizer Coefficients[a] α_1	Fertilizer Coefficients[a] α_2
Corn	Cobb-Douglas	3.2839	.3532	
		(.7476)	(.0885)	
Corn	Translog	.00023	8.2887	−3.1903
		(.00052)	(1.7738)	(.6948)
Oats	Cobb-Douglas	6.0863	.3101	
		(1.0067)	(.0531)	
Oats	Translog	.9187	1.6013	−.4260
		(.6265)	(.4473)	(.1442)

Note: Figures in parentheses are standard errors, estimated under the assumption of homoscedasticity.
[a] See equations (11) and (12) for functional forms.

derivation in the translog case, it is again found that the usual specification with a log linear disturbance is the special case of the specification of this paper where $\beta_2 = \alpha_2$ holds in addition to the conditions in (14) and (15).

It is further interesting to compare the standard error estimates in tables 1 and 3 (although they only apply asymptotically). One finds in all cases except constant terms that standard error estimates are larger in table 3 than in table 1. But the estimator in the third stage is asymptotically efficient and thus possesses lower standard errors (asymptotically) than the first-stage estimator, i.e., the true standard error estimates in table 1 should be higher than those in table 3. Of course, the standard error estimates in table 1 are not applicable under the general stochastic specification used in obtaining table 3 estimates. But, unfortunately, it is often the case in econometric practice to assume homoscedasticity when risk aspects of a study are presumed unimportant, or information to the contrary is not readily apparent. The comparison of tables 1 and 3 illustrates the potential danger of assuming homoscedasticity if, in fact, it is not applicable. In other words, if functional forms such as (3) are applicable in reality, the standard practice of assuming homoscedasticity could correspond to the first-stage estimation of this paper. But, if so, the associated statistics apparently would be misleading and imply much more precise estimation than is warranted.

Implications of Assuming Log Linear Disturbances

Because the more common approach is to assume homoscedasticity with log-linear disturbances (rather than additivity as in the first-stage case of this paper), it is interesting to pursue further the misspecification problems associated with log linearity [if (3), in fact, holds]. To investigate this problem, the regression results in table 4 have been derived under the usual assumption of log linearity. Comparing with table 1, the resemblance of statistics, aside from those pertaining to the constant term, is remarkable. This is true with respect to standard error estimates as well as coefficient estimates. Furthermore, the difference in constant term estimates is explained by the fact that only those in table 4 are estimated in logarithmic terms (see Zellner, Kmenta, Dreze for a discussion of related problems). Thus, the methodology associated with table 4 apparently is subject to the same criticism made of the homoscedasticity assumption above in comparing tables 1 and 3. That is, use of the common but simple approach of log linearity in disturbances (with homoscedasticity) when, in fact, (3) is applicable, apparently can lead to much smaller standard error estimates than are justified (asymptotically). This is true because the table 3 estimates are asymptotically efficient and their standard errors are much larger. Thus, any hypothesis testing based on tables 1 and 4 could be very misleading.

It appears, however, that there are even more serious problems of bias associated with log linear stochastic specification when, in fact, (3) is applicable. In logarithmic terms, and assuming log linearity of f, the specification in (3) becomes

$$(16) \qquad \begin{aligned} \ln y_t &= \ln f(X_t, \alpha) + u_t \\ &= (\ln X_t)'\alpha + u_t, \end{aligned}$$

where

$$u_t = \ln\left[1 + \frac{\epsilon_t h(X_t, \beta)}{f(X_t, \alpha)}\right].$$

Table 4. OLS Estimates under the Assumption of Homoscedastic Log-Linear Disturbances

Crop	Functional Form	Constant Term $\ln A$	Fertilizer Coefficients α_1	α_2	R^2
Corn	Cobb-Douglas	2.5667 (.1310)[a]	.3246 (.0413)		.219
Corn	Translog	2.8830 (.6417)	.0961 (.4556)	.0785 (.1560)	.220
Oats	Cobb-Douglas	2.4897 (.1337)	.3855 (.0390)		.308
Oats	Translog	1.8026 (.4557)	.8286 (.2838)	−.1354 (.0859)	.316

[a] Figures in parentheses are standard errors.

Thus, where $X = (ln\ X_1, \ldots, ln\ X_T)'$ and $V = (u_1, \ldots, u_T)'$, the OLS estimate α^* in (16) has expectation

$$E(\alpha^*) = \alpha + (X'X)^{-1}X'E(V) \neq \alpha$$

since $E(V) < 0$ by Jensen's inequality and concavity of u_t in ϵ_t,

$$E[u_t(\epsilon_t)] < u_t E(\epsilon_t) = 0.$$

Of course, OLS also is inconsistent because the magnitude of bias does not generally depend on T (see Kmenta for a similar discussion). Taking expectations of a Taylor-series expansion of u_t,

$$E(u_t) = -\frac{1}{2}\,\frac{E(\epsilon_t^2)h^2(X_t, \beta)}{f^2(X_t, \alpha)} - \frac{1}{4}\,\frac{E(\epsilon_t^4)h^4(X_t, \beta)}{f^4(X_t, \alpha)} \ldots,$$

it also is evident that the bias is necessarily small only when instability in production is small (relative to expected production). One must then question the use of log linear estimates of f if the arguments in the first part of this paper hold.

Conclusions and Summary

As argued in the first part of this paper, traditional production-function formulations are uninformative with respect to risk. The flexibility given by (3), however, is within traditional neoclassical orthodoxy with respect to f (as far as mean response) but appears superior for risk analysis. For firm decision problems and public policy, it seems the generalization suggested by (3) potentially offers greater flexibility in describing stochastic technological processes and related behavior.

In summary, the major conclusions of this paper are as follows:

(*a*) Traditional production-function formulations are very restrictive and, in particular, imply that changes in inputs are directly related to changes in the variance of output.

(*b*) This restriction contradicts other research findings.

(*c*) Hence, traditional production-function estimates may be of little use in evaluating policies—particularly those which can have a risk-reducing effect on output.

(*d*) A simple reasonable production-function specification must apparently contain at least two components—one explaining the effect of input on expected output and another explaining the effects of input on variability of output.

(*e*) Such a production function is given by (3), and a three-step NLS procedure (with or without variance components) is proposed. Use of a maximum likelihood procedure (without variance components) to attain efficiency in estimating $h(\cdot)$ is also discussed.

(*f*) An application indicates that fertilizer has a variance-increasing effect on yield; but the marginal variance contribution is much smaller than the standard log-linear disturbance approach would indicate.

(*g*) Empirical results indicate that estimation assuming the homoscedastic log-linear disturbance case can lead to standard error estimates that are misleading and indicate much greater precision in estimation than is, in fact, obtained.

[*Received June 1977; revision accepted October 1978.*]

References

Anderson, Jock. "Sparse Data, Climatic Variability, and Yield Uncertainty in Response Analysis." *Amer. J. Agr. Econ.* 55(1973):77–82.

Bardhan, P. "Variations in Forms of Tenancy in a Peasant Economy." *J. Devel. Econ.* 4(1977):105–18.

Batra, R. "Resource Allocation in a General Equilibrium Model of Production Under Uncertainty." *J. Econ. Theory* 8(1974):50–63.

Borch, K. "A Note on Uncertainty and Indifference Curves." *Rev. Econ. Stud.* 36(1969):1–4.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau. "Transcendental Logarithmic Production Frontiers." *Rev. Econ. Statist.* 55(1973):28–45.

Crawford, R. "Implications of Learning for Economic Models of Uncertainty." *Int. Econ. Rev.* 14(1973):587–600.

Day, Richard. "Probability Distributions of Field Crop Yields." *J. Farm Econ.* 47(1965):713–41.

de Janvry, Alain. "The Generalized Power Production Function." *Amer. J. Agr. Econ.* 54(1972):234–37.

Feldstein, M. "Production Uncertainty with Uncertain Technology: Some Economic and Econometric Implications." *Int. Econ. Rev.* 12(1971):27–36.

Fuller, Wayne. "Stochastic Fertilizer Production Functions for Continuous Corn." *J. Farm Econ.* 47(1965):105–19.

Halter, A. N., H. O. Carter, and J. G. Hocking. "A Note on the Transcendental Production Function." *J. Farm Econ.* 39(1957):966–74.

Hildreth, C., and J. Houck. "Some Estimates for a Linear Model with Random Coefficients." *J. Amer. Statist. Assoc.* 63(1968):584–95.

Hoch, Irving. "Estimation of Production Function Pa-

rameters Combining Time Series and Cross-Section Data." *Econometrica* 30(1962):34–53.

Horowitz, I. *Decision Making and the Theory of the Firm.* San Francisco: Holt, Rinehart & Winston, 1970.

Just, Richard E., and Rulon Pope. "Stochastic Representation of Production Functions and Econometric Implications." *J. Econometrics* 7(1978):67–86.

Kelejian, H. "The Estimation of Cobb-Douglas Type Functions with Multiplicative and Additive Errors: A Further Analysis." *Int. Econ. Rev.* 13(1972):179–82.

Kmenta, J. *Elements of Econometrics.* New York: Macmillan Co., 1971.

Maddala, G. "The Use of Variance Components Models in Pooling Cross-Section and Time-Series Data." *Econometrica* 39(1971):939–53.

Magnusson, Gudmunder. *Production Under Risk: A Theoretical Study.* Uppsala: Almqvist and Wiksells, 1969.

Malinvaud, E. "The Consistency of Nonlinear Regressions." *Annals of Math. Statist.* 41(1970):956–69.

Moscardi, Edgardo, and Alain de Janvry. "Attitudes Toward Risk among Peasants: An Econometric Approach." *Amer. J. Agr. Econ.* 59(1977):710–16.

Radner, Roy, and Michael Rothschild. *Notes on the Allocation of Effort.* Center for Research in Management Sciences Tech. Rep. No. OW-1, University of California, Berkeley, 1974.

Rothenberg, T. J., and K. Smith. "The Effect of Uncertainty on Resource Allocation in a General Equilibrium Model." *Quart. J. Econ.* 85(1971):440–59.

Sadan, Ezra. "The Investment Behavior of a Farm Firm Operating under Risk." *Amer. J. Agr. Econ.* 52(1970):494–504.

Stiglitz, Joseph E. "Incentives and Risk Sharing in Sharecropping." *Rev. Econ. Stud.* 41(1974):219–55.

Theil, Henri. *Principles of Econometrics.* New York: John Wiley & Sons, 1971.

Turpin, F., and J. Maxwell. "Decision-Making Related to Use of Soil Insecticides by Indiana Corn Farmers." *J. Econ. Entomol.* 69(1976):359–62.

Wallace, T. D., and Ashiq Hussain. "The Use of Error Components Models in Combining Cross-Section with Time-Series Data." *Econometrica* 37(1969):55–72.

Wolgin, J. M. "Resource Allocation and Risk: A Case Study of Smallholder Agriculture in Kenya." *Amer. J. Agr. Econ.* 57(1975):622–30.

Zellner, Arnold. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *J. Amer. Statist. Assoc.* 57(1962):348–68.

Zellner, A., J. Kmenta, and J. Dreze. "Specification and Estimation of Cobb-Douglas Production Function Models." *Econometrica* 34(1966):784–95.

Appendix

Generalized Estimation

Consider multistage estimation of the error components version of the production function model specified by (10). In this case, a first-stage regression, such as suggested by (6), is still possible and consistency for α is obtained where ϵ^*_{ti} is defined by

$$\epsilon^*_{ti} = h^{1/2}(X_{ti}, \beta)(\epsilon_{ti} + w_t).$$

However, one finds in place of (7) a regression equation of the form

$$\text{(A.1)} \quad (\epsilon^*_{ti})^2 = h(X_{ti}, \beta)(1 + \sigma) + u_{tii}, \; E(u_{tii}) = 0,$$

because $E[(\epsilon^*_{ti})^2] = h(X_{ti}, \beta)(1 + \sigma)$, where $t = 1, \ldots, T$, and $i = 1, \ldots, N$. Furthermore, since $\epsilon^*_{ti}\epsilon^*_{tj}$, $i \neq j$, no longer has a zero expectation [as with $\epsilon_t\epsilon_\tau$, $t \neq \tau$, corresponding to (7)], one must also consider

$$\text{(A.2)} \quad \epsilon^*_{ti}\epsilon^*_{tj} = h^{1/2}(X_{ti}, \beta)h^{1/2}(X_{tj}, \beta)\sigma + u_{tij}, \; E(u_{tij}) = 0,$$

for $i \neq j$ since $E(\epsilon^*_{ti}, \epsilon^*_{tj}) = h^{1/2}(X_{ti}, \beta)h^{1/2}(X_{tj}, \beta)\sigma$, where $t = 1, \ldots, T$; $i = 1, \ldots, j - 1$; and $j = 1, \ldots, N$. It is still the case, however, that $E(\epsilon^*_{ti}\epsilon^*_{\tau j}) = 0$ if $t \neq \tau$ so only the relationships in (A.1) and (A.2) must be considered.

Comparing with the earlier derivation and, in particular equation (8), it is no longer possible even with log-linear functions to combine (A.1) and (A.2) into a linear second-stage equation replacing (8) because $\epsilon^*_{ti}\epsilon^*_{tj}$ can possibly be negative; thus, its logarithm does not exist. An alternative second-stage regression equation would combine equations (A.1) and (A.2) directly:

$$\text{(A.3)} \quad \epsilon^*_{ti}\epsilon^*_{tj} = [\delta_{ij}\beta^*_0 + (1 - \delta_{ij})\bar{\beta}_0]h^{1/2}(X_{ti}, \beta)h^{1/2}(X_{tj}, \beta) + u_{tij},$$

where $t = 1, \ldots, T$; $i = 1, \ldots, j$; and $j = 1, \ldots, N$; $\beta^*_0 = 1 + \sigma$, $\bar{\beta}_0 = \sigma$, δ_{ij} is the Kronecker delta, and the ϵ^*_{tk} are replaced by their first-stage estimates. Also, for identification purposes, any multiplicative constant term in h must be combined with β^*_0 and $\bar{\beta}_0$. The addition of variance components in estimation thus suggests nonlinear estimation in the second stage if asymptotic efficiency is to be obtained in the third stage. That is, one cannot choose to disregard the observations generated by (A.2) and still identify σ;[8] when (A.2) is used, the log-linear representation cannot be used because $\epsilon^*_{ti}\epsilon^*_{tj}$ is possibly negative. It can be shown following Just and Pope that NLS estimates of (A.2) are consistent under the general specification in (9) so long as X satisfies conditions for consistency in the first stage and ϵ_{ti} has bounded fourth moments.

Thus, a third-stage, nonlinear, generalized least-squares regression of y_{ti} on X_{ti}, using the equation

$$\text{(A.4)} \quad y_{ti} = f(X_{ti}, \alpha) + \epsilon^*_{ti},$$

is possible where the covariance matrix is estimated by predicted values from the second-stage regressions corresponding to (A.3). It can be shown that the α estimator thus obtained is consistent and asymptotically efficient along the same lines as in the case considered by Just and Pope without error components.

---

[8] This is true so long as h contains a multiplicative constant term (so that homoscedasticity is a special case), in which case the estimate of β_{i*} would be an estimate of the multiplicative constant times $1 + \sigma$.

Financial Impacts of Government Support Price Programs

Michael Boehlje and Steven Griffin

Recent proposals to index government support prices based on the cost of production will have significant differential impacts on farms with different size and financial characteristics. Simulation analyses indicate that since such proposals result in both increased income and decreased risk and thus capitalization rates, land values could increase dramatically with the larger, high-equity operator best able to pay the higher price for additional land. Furthermore, the guaranteed cash flow from such a program enables the higher equity firm to grow more rapidly in terms of net worth and land ownership as well as exhibit higher levels of family living compared to smaller, highly leveraged firms.

Key words: price support programs, financial impacts, land values, firm growth.

Various forms of income and price support programs have been a part of government farm policy since early in the twentieth century. The most recent farm program legislation, the Food and Agriculture Act of 1977, uses the concept of "target prices" to activate income subsidies to farmers if market prices should decline below these "target" or support levels. Current farm policy programs include provisions to increase the support prices for feed grains based on USDA cost-of-production studies that reflect changes in the prices and technology of production inputs. In reality, this adjustment process is a form of cost or inflation indexing as practiced in many other sectors of the U.S. economy. Controversy has arisen in specification of the indexing process concerning the measurement of costs, particularly the annual charge for services of land, and the procedure (if any) to be used in reflecting land value increases in the index.

In essence, the support prices operate to set a floor in terms of prices and price expectations of producers. They also influence the cash flow of the farm business and thus its debt-carrying and debt-servicing capacity. The purpose of this paper is to discuss and document the impact of support price programs on investment and financing behavior of producers with different characteristics in different size categories. The working hypothesis is that indexed support prices will increase the guaranteed cash flow of the farm business and reduce the financial risk, resulting in increased bid prices for durable assets such as land, increased debt-carrying capacity and thus financial leverage, and more rapid rates of growth of the firm. Analysis of these impacts by size of firm and characteristics of the entrepreneur will provide implications concerning the effect of support price policies on size distribution and the ownership and control of agricultural resources.

Previous Studies

Analysis of the impact of government price and income support programs on asset values, particularly land, is not new. Hedrick documented the impact of peanut price support and allotment programs on farmland values. Similar analyses have been completed by Boxley and Gibson and Boxley and Anderson for peanuts and tobacco, respectively. A recent study by Reynolds and Timmons also confirms that government farm program payments have been capitalized into land values. However, the emphasis on the cost-of-production approach to specifying support prices provides a much more direct linkage between government support programs and

---

Michael Boehlje is a professor in the Department of Economics and Steven Griffin is a research associate at the Center for Agriculture and Rural Development, Iowa State University.

Journal Paper No. J9399 of the Iowa Agricultural and Home Economics Experiment Station, Ames. Project No. 2066.

land values. Penn and Brown have reviewed the basic characteristics and concepts of such cost-indexed support programs, while Sharples and Krenz have discussed the relationship between cost of production as a basis for support price programs and the earlier concept of parity. Harris has developed a concise theoretical model to illustrate relationships between cost-indexed support prices and land values.

Focus of the Study

The present research extends Harris's work in three important dimensions. First, in contrast to Harris' assumption of a fixed, uniform price distribution, a more general and moving probability distribution is used to describe initial price expectations on the part of producers, and the mechanism for adjusting producer price expectations based on the support price program is much less restrictive. Second, the land investment decision is integrated along with financial constraints within the framework of a dynamic firm growth model. Thus, the effect of government support price programs on the ability of firms with different size and financial characteristics to expand by land acquisition is explicitly evaluated along with the bid price for land. Third, the impact of various support-price program parameters on the cash flow of the firm and the ability to finance a land purchase at the specific bid price are analyzed. So the focus of this work, in contrast to previous studies, is the expected financial impacts of government support price programs and the ability of firms with different characteristics actually to participate in the real estate market and expand in size, as well as the expected impact of such programs on real estate values. The results of this analysis are particularly responsive to the comment of Gardner and Pope that, "the impact of price supports might well have been output-increasing, but whether or not the distribution of benefits favors large farms or are proportional to size has never to our satisfaction been demonstrated" (p. 297).

Certainly the numerical results presented here presume a permanency of the government price support program and expectations on the part of farmers and landowners that such a program once in place will not be terminated abruptly. Such a presumption seems appropriate because the objective of the analysis is to evaluate the potential impact of a cost-of-production indexed support program if it is implemented and maintained. Quite possibly the results presented here, along with other analyses of the impacts of government support programs, might have an impact on the initiation and/or termination of such programs.

The following section will review the conceptual framework for the numerical model with emphasis on incorporating price-support program parameters and price expectations into a firm valuation model. A numerical model will then be developed to use in investigating the working hypothesis. The results of this numerical analysis will be reviewed with a final section devoted to conclusions and implications.

The Conceptual Framework

The numerical model must be structured to indicate the impact of support price programs on price expectations and thus income and value of the firm, given specified financial characteristics and constraints. The conceptual base for the analysis comes from a combination of the theory of the firm and the theory of asset valuation (Vickers).

Specifically, the value of an asset or the firm (V_t) is equal to the expected income stream $[E(R_t)]$ capitalized by the appropriate rate (k_t).

$$(1) \qquad V_t = \frac{E(R_t)}{k_t}.$$

The expected income stream is defined in equation (2) as the expected price $[E(P_t)]$ minus production costs (C_t) times the output (Q_t) minus interest on debt (ηD_t).

$$(2) \qquad E(R_t) = [E(P_t) - C_t]\cdot Q_t - \eta D_t.$$

Production costs are composed of variable cost (TVC), machinery ownership costs (XMC), overhead (OVH), management ($MGMT$), and land charges (XLC) and are assumed to increase at a specified rate (θ_1) over time.

$$(3) \qquad C_o = TVC + XMC + OVH + MGMT + XLC,$$

$$(4) \qquad C_t = (1 + \theta_1)\, C_{t-1}.$$

The production function of equation (5) specifies output as a function of assets (A_t), with

productivity increases (θ_3) over time explicitly recognized.

(5) $$Q_t = \phi A_t (1 + \theta_3)^{t-1}.$$

The financial structure of the firm is defined in equation (6) as assets (A_t) equal to equity (O_t) plus debt (D_t).

(6) $$A_t = O_t + D_t.$$

The government price program enters explicitly in the specification of price expectations as indicated by equations (7) and (8). A dynamic, support-price, adjustment mechanism is specified in equation (7), where the support level (SL_t) is a function of the policy variable of the amount and type of costs to include (¶) and the cost of production per unit of output (C_t). The support level is also assumed downward inflexible.[1]

(7) $$SL_t = G(\P, C_t);\ SL_t \geq SL_{t-1}.$$

This support level influences the price distribution and expectation model as summarized in equation (8).[2]

(8) $$E(P_t) = \int_{SL_t}^{\infty} N(p, P^*_t, \sigma_{p^*_t}{}^2)p\,dp + \int_0^{SL_t} N(p, P^*_t, \sigma_{p^*_t}{}^2)dp\,SL_t,$$

where $P^*_t = P^*_o(1 + \theta_2)^{t-1}$ and $\sigma_{p^*_t}{}^2 = (\pi P^*_o)^2$. The price distribution is comprised of two components, the proportion above the dynamically adjusted support price [the first argument of equation (8)], and the proportion that is truncated because it is below the support price [the second argument of equation (8)]. In essence, the truncated area is redistributed over the remaining portion of the distribution, thus affecting both the mean and variance of the price expectations distribution. Although numerous techniques of redistribution are possible, the current procedure calls for "stacking" the truncated area of the distribution at the support level. The original expected product price is also assumed to be inflating at a rate of $(1 + \theta_2)$ per year due to macroadjustments to supply and demand conditions exogenous to the model.

The capitalization rate (k_t) is specified in equation (9) as a function of the opportunity cost of capital (CC), the marginal tax rate (MTR), the interest rate (η), the down payment on the real estate loan (DP), the expected growth in net income (GNI), and the expected growth in land values (GLV).

(9) $$k_t = CAP\ (CC, MTR, \eta, DP, GNI, GLV).$$

The specific functional form of this relationship used in the model was developed by Lee and Rask (p. 986). Equation (10) indicates that the opportunity cost of capital is a function of the variance in price ($\sigma_{P_t}{}^2$) with a risk-free rate (W_1) serving as a lower bound. It is assumed that potential land purchasers are risk-averse. The variable W_2 is a maximum allowable opportunity cost of capital.

(10) $$CC = \text{MAX}\ (W_1, W_2 - \delta/\sigma_{P_t}{}^2).$$

The variance of price is defined in equation (11) as the second moment of the modified price expectations distribution.

(11) $$\sigma_{P_t}{}^2 = \int_{SL_t}^{\infty} N(p, P^*_t, \sigma_{p^*_t}{}^2)p^2dp + [\int_0^{SL_t} N(p, P^*_t, \sigma_{p^*_t}{}^2)dp\,SL_t^2] - E(P_t^2).$$

Finally, the utilization of debt is constrained by equation (12) to a proportion of the equity capital (O_t)—debt to equity ratio, and by equation (13) to a proportion of the expected income of the firm [$E(R_t)$]—cash flow for debt servicing.

(12) $$D_t \leq \Delta O_t,$$

(13) $$D_t \leq \xi E(R_t).$$

The parameters of the model include the interest rate (η), the production response parameter (ϕ), the price expectations and support price parameters (P^*_o, ¶, π, SL_o), the expected rates of inflation (θ_1, θ_2, and θ_3), the parameters of the opportunity cost of capital equation (W_1, W_2, and δ), and the financial constraint parameters (Δ and ξ). The impact of various values for these parameters will be demonstrated in the numerical results. Also, for numerical application, a set of initial conditions, or values, must be specified for A_t, O_t, D_t, C_o, MTR, DP, GNI, GLV. Different values for these initial conditions will simulate the behavior of different entrepreneurs with different farm sizes and financial structures.

[1] Although this assumption of a downward inflexible support level is not essential for the numerical analyses, it appears realistic. The final results in terms of land values, firm size, and distributional impacts assuming a downward flexible support price were very similar to those presented here.

[2] The price distribution described in equation (8) represents a normal distribution with first and second moments defined by P^*_t and $\sigma_{P}{}^2$, respectively. However, any probability distribution could be defined in the model.

The Numerical Model

A computer simulation model was constructed to parallel the conceptual model of equations (1)–(13) and generate numerical results for Midwest corn farmers. In essence, the model includes three assets—land, all other productive assets (machinery, crop inventories), and cash—and one commodity—corn. The flow chart of figure 1 summarizes the structure and data requirements of the simulation model. The first step of the analysis is to initialize various program parameters including the firm size and financial structure, efficiency characteristics, lending constraints, inflation rates, and government support program parameters. Next, the cost of production per unit of output (corn) is calculated for each firm using budget information on the quantities of various input items, output as determined by the production function, and the inflation parameter to reflect increased costs attributable to input price increases.[3] The costs of production for all firms are weighted to obtain an "aggregate" cost of production. The weights are chosen to reflect the relative proportion of U.S. total production contributed by each representative farm.

The "aggregate" cost of production is combined with other parameters describing the government support price program (cost items to be included in the support level calculation, assumed management and land charges included in the support level, and the percentage of total cost per unit covered by the support program) to determine the actual level of the government support price per unit of output. This support price is then incorporated in a price expectations model which includes a dynamic price adjustment mechanism tied to the support price. Figure 2 illustrates the adjustment mechanism included in the model. Panel 1 of figure 2 indicates the original price distribution that the producer faces (without a price support program) and the resulting mean and variance of this distribution. But, through the price support program, the left-hand tail of the original distribution is truncated and the truncated portion is then "stacked" at the support level as illustrated in panel 3 of figure 2. This revised distribution now has a higher mean (first moment) and lower variance (second moment) than the original distribution, thus increasing the expected income, lowering

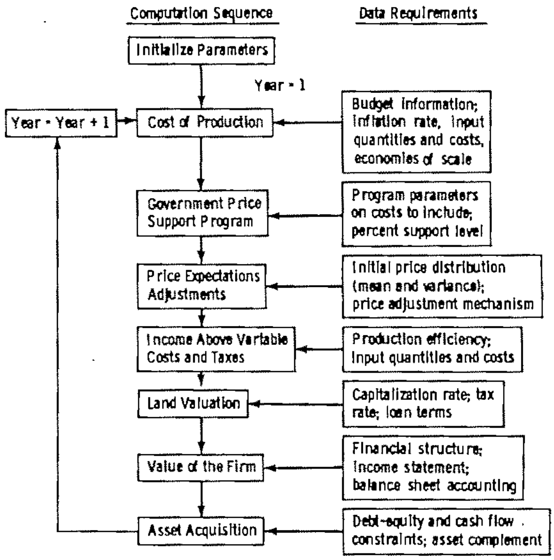


Figure 1. The simulation model

the capitalization rate, and increasing the value of land and the firm. If the government program includes a land charge in the computation of the cost of production, the increased land value will enter the support price program in the following year and result in a higher support level. As input price inflation and increasing land values spiral upward the cost of production, more of the price distribution is truncated, expected income rises, and the variance declines further as illustrated in panel 4 of figure 2. Thus, the indexing impact of the government support price program is clear.

Once the price expectations information has

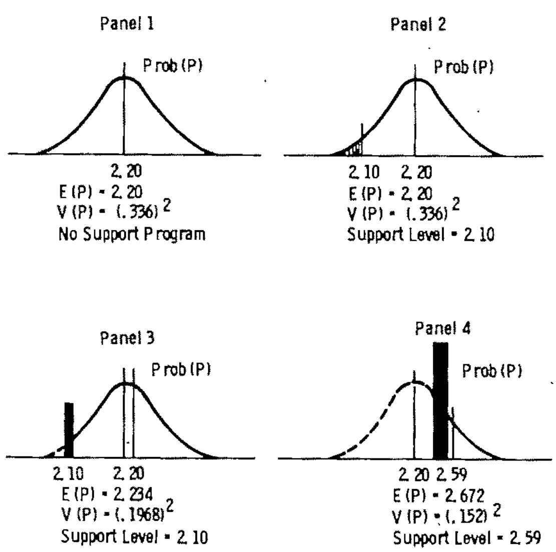


Figure 2. The support price and price-distribution adjustment mechanism

[3] Illinois farm record data (Scott) were used to construct cost curves exhibiting economies of scale which were used to adjust FEDS budget information (Krenz) for Central Iowa.

been generated, the annual income above variable cost and taxes can be calculated. This income figure adjusted for income taxes and overhead, along with the opportunity cost of capital as adjusted by the aforementioned changes in the variance of the price distribution, mortgage interest rates, expectations of future gains in land values, and income per acre are used to determine the maximum bid value of land to the firm using capitalization concepts. The "market" price of land is calculated by aggregating bid prices for each category of farm by estimates of its historic purchases in the national land market. Note that in determining the market value of land, the farms are not bidding against one another as if they were at a single land auction. The aggregation procedure used here to obtain a "market value" recognizes that successful bidders in local land markets may not have to pay their maximum bid price, depending upon the strength and availability of local competitive bidders. The "aggregated" land value (and assumed market price) along with the income generated during the year is used to adjust the financial statement and determine the value of the firm. Finally, the acquisition of additional production assets, including land, uses earnings after consumption and additional debt as constrained by the debt-equity and repayment ratios.[4] It is assumed that land can be acquired in increments of 40 acres or more at the "market value," and the acquisition of land also requires the purchase of a complement of "other assets" unless that complement has already been accumulated. This completes one year of the analysis, and the program returns to the initial calculations and cycles through the computations for succeeding years.

Farm Situations Analyzed

The various parameters and farm situations included in the analysis are summarized in table 1. With respect to the three different farm types, Farm A is typical of the young, beginning operator with a 160-acre land base, only a 30% equity in his unit, and some off-farm income. Farm B represents a more typical operator who has an average size unit and 50% equity in his operation. Farm C represents a well-established farmer with a sizeable operation and a relatively low debt obligation (a 30% debt to equity ratio).

Numerical Results

The numerical results generated by the simulation model are presented in tables 2 through 6. Tables 2 and 3 summarize the costs, prices, land values, farm growth, and financial characteristics for the three farms, using a recently proposed set of government support-price program assumptions. The sensitivity of the results to different financial conditions, and government program parameters (rate of land return included in the cost of production, and the percentage of cost of production supported by the government program) are summarized in tables 4, 5, and 6, respectively.

Land Prices and Firm Growth

Initial analyses assume 90% of the cost of production is supported by the government with a price support program, the gross return to land calculated in the cost of production is 3.5% of the current market value, and expected annual increase in corn prices is 2%. Annual cost, support and expected prices, net income and bid prices for land over a fifteen-year simulation period are summarized in table 2 for the three firms analyzed. For example, for the smaller, highly leveraged farm, the total nonland costs in year one amount to $1.62 per bushel, with total cost of production per bushel including the land charge of $2.18. Based on the price distribution used in the analysis, the expected price in the first year is $2.23, with a standard deviation of $.1968. The support price is set at $2.10 in the first year in accordance with current farm legislation.[5] Based on a 110 bushel per acre yield and the cost indicated earlier, the annual net income which could be allocated to the land resource is $56.68 per acre. Using the capitalization formula suggested by Lee and Rask, an implicit capitalization rate of 3.853% is esti-

[4] Family-living expenditures are estimated as 75% of net farm income less income taxes with a minimum level of $5,000 in real terms. These expenditures are significant in two dimensions: (*a*) they have an important impact on the ability to acquire additional assets because living expenditures are a direct drain on cash flow and thus reduce the debt-servicing capacity of the firm, and (*b*) they measure the standard of living the farm family can expect to achieve as expansion occurs.

[5] Note that a $2.10 government support price is higher than would be calculated on the basis of a 90% of cost-of-production program.

Table 1. Parameter Values and Initial Conditions

Parameters[a]			
Expected inflation rates or increases in	(%)		
Production costs θ_1	6		
Price received θ_2	2		
Yield per unit of input θ_3	1		
Net income per acre *GNI*	3		
Land price *GLV*	5		
Price distribution (initial)			
Expected price (mean) P^*_t	\$2.20		
Variance σ_{P_t}	$(.336)^2$		
Support program			
Percent of cost of production[b] ¶	80, 90, 100		
Initial support program SL_0	\$2.10		
Mandated return to land[c]	1.5, 3.5		
Capitalization rate			
Risk-free opportunity W_1	5.845		
Maximum allowable rate W_2	10.0		
Long-term mortgage rate η	8.75		
Short-term interest rate for other debt *MR*	10.00		
Initial Conditions			
Land price	\$1770/acre		
Yield ϕ	110 bu./acre		
Farm characteristics			
	Farm A	Farm B	Farm C
		\$	
Size (acres)	160	320	640
Assets	335,700	673,400	1,342,800
Liabilities	234,990	336,700	402,840
Equity	100,710	336,700	939,960
Annual debt service	22,368	33,586	43,346
Average tax rate[d] (%)	11	16	25
Cost of production (\$/bu.)	2.18	2.13	2.03
Off-farm income	10,000	0	0
Land price aggregation weight	.10	.20	.70
Cost of production aggregation weight	.10	.20	.70

[a] Where multiple parameter or initial condition values are listed, additional computer analyses were completed to indicate the sensitivity of the results to these different values.
[b] The proportion of the calculated cost of production that will be supported by the support price program.
[c] The return on the current land value that is to be included in the cost of production calculation for the support price program. Land taxes and maintenance costs of 1.5% must be subtracted to obtain net return.
[d] The marginal tax rate is double the average tax rate.

mated.[6] This combination of annual net return and capitalization rate results in a bid price for land per acre of \$1,471 for the small unit.

Note that in subsequent years of the simulation, the increase in input prices due to inflation results in an increase in nonland cost. Furthermore, the land charge increases because of the 3.5% mandated return to land that is part of the government support price program. Total cost of production increases to \$5.54 per bushel by year fifteen. Thus, the cost-of-production approach to determining support prices, along with increases in per unit cost due to inflation, result in a twofold increase in the nominal support price for corn during the 15-year period. As indicated in figure 2, this increase in the support price level truncates the left tail of the price distribution, increasing the expected price and decreasing the variance of price. Even though costs may increase faster than prices, resulting in a reduction in net return, the reduced price variance may lower the capitalization rate so that the bid price for land actually increases. However, at the 90% level of government price support, the cost-price squeeze is sufficiently

[6] The income capitalization rate can be and is below the risk-free rate of return because the capitalization rate is reduced by the expected growth rate in the value of land.

Table 2. Costs of Production, Government Price Supports, Expected Prices, Income, and Land Values by Farm Situation and Year of Simulation

Year of Simulation	Non-land Costs ($/bu)	Total Cost of Production ($/bu)	Govt. Support Price ($/bu)	Expected Price Received ($/bu)	Standard Deviation of Expected Price ($/bu)	Annual Net Income ($/acre)[a]	Land Capitalization Rate (%)	Land Bid Price ($/acre)
				Farm A				
1	1.62	2.18	2.10	2.23	0.1968	56.68	3.853	1471
5	2.03	2.57	2.15	2.35	0.2372	37.89	3.201	1184
10	2.72	3.43	2.81	2.85	0.0989	31.33	1.413	2218
15	3.70	5.54	4.58	4.58	0.0359	176.24	2.485	7092
				Farm B				
1	1.57	2.13	2.10	2.23	0.1968	66.18	4.041	1638
5	1.96	2.50	2.15	2.35	0.2372	80.70	4.754	1697
10	2.52	3.23	2.81	2.85	0.0989	99.55	3.277	3038
15	3.40	5.24	4.58	4.58	0.0359	206.99	2.728	7588
				Farm C				
1	1.47	2.03	2.10	2.23	0.1968	100.75	5.152	1955
5	1.74	2.28	2.15	2.35	0.2372	103.89	5.435	1912
10	2.25	2.96	2.81	2.85	0.0989	127.43	3.894	3272
15	3.00	4.84	4.58	4.58	0.0359	248.14	3.055	8123

[a] Calculation of the net income per acre for Farm A for year 1 will illustrate the computations. Variable values include: $YLD = 110$, $E(P) = 2.234$, $TVC = .835$, $XMC = .386$, $OVH = 28.20$, $XLTAX = .015$. Thus, the annual net income per acre for Farm A for year 1 is gross receipts (110 × 2.234 = 245.74) minus operating costs (.835 = .386) × 110 = 134.31 minus overhead (28.20) minus land taxes (.015 × 1770 = 26.55) which equals $56.68. Farm B's and C's annual net income is calculated similarly except that the overhead costs for Farm C are already covered and thus not charged against the additional parcel of land.

severe for the smaller firm that its bid prices for land decline for the first few years even though the capitalization rate is decreasing. At the 100% support level, the government program provides both a higher level of returns per acre and significant reductions in risk, and thus an increasing land price spiral is sustained for all three farms, as will be indicated later.

Given the parameters specified for this analysis, the price distribution collapses to the support price by the twelfth year so that the price expectation is the support price of $3.43. By the fifteenth year of the simulation, the bid price for land by the smaller, highly leveraged farm has been pushed to $7,092 per acre by the support price program. The same phenomenon occurs for the typical (Farm B) and larger (Farm C) units, where bid prices have increased to $7,588 per acre and $8,123 per acre, respectively, by year fifteen. The data in table 2 indicate that over time the larger, lower leveraged farm can continually pay a higher price for the land than the smaller, highly leveraged unit. This is due in part to a higher residual return to land primarily based on economies of size. So the support price program would improve the bidding potential of the larger, high-equity farm units compared to smaller, low-equity farms over time.

The financial and growth implications of the support program for the three representative firms are summarized in table 3. For the small, highly leveraged unit, firm size in acres remains unchanged for the entire fifteen-year period even though total assets and net worth increase dramatically due to inflation in the value of land. Expansion is not financially feasible for this firm because land values and, thus, cash down-payment and debt-servicing requirements are increasing more rapidly than the cash income of the farm operation. Other assets also increase as inflation pushes up the value of durable inputs such as machinery and equipment. In fact, net worth increases more than tenfold during the fifteen-year period due primarily to asset appreciation. By the end of the fifteenth year, net worth totals $1,225,850 and the debt-to-asset ratio is .146. This low debt to asset ratio occurs for two interrelated reasons. With land values increasing because of the support price program, the value of the initial endowment of land plus new purchases, and thus the value of assets, increases at a rapid rate. In contrast, the initial endowment

Table 3. Income, Assets, and Debt Statement by Farm Situation and Year of Simulation

Year	Income Less Taxes	Family Consumption	Total Land Value	Acres in Firm	Total Assets	Total Debt	Total Equity	Annual Growth Rate in Equity	Debt to Asset Ratio
				Farm A					
1	8439	6330	294946	160	350926	233184	117742	15.62	0.6645
5	9895	7421	283970	160	361890	226097	135793	5.98	0.6248
10	13787	10340	497285	160	613770	217541	396229	13.70	0.3544
15	33147	24860	1253527	160	1435158	209308	1225850	16.66	0.1458
				Farm B					
1	10504	7878	589891	320	701403	332575	368828	9.11	0.4742
5	12854	9640	567940	320	712655	316574	396081	3.25	0.4442
10	13266	9949	1608337	517	1746975	589560	1157415	12.35	0.3375
15	65766	49324	4415541	564	4655336	680410	3974927	16.46	0.1462
				Farm C					
1	40698	30524	1179783	640	1402687	394742	1007945	6.98	0.2814
5	43024	32268	1683490	949	1863937	762961	1100976	3.16	0.4093
10	64674	48505	3585376	1154	3827919	956464	2871454	11.17	0.2499
15	170954	128215	10296190	1314	10643179	1411657	9231521	15.23	0.1326

of debt plus any additional debt incurred to buy additional land must be repaid according to a specified amortization schedule. So even though debt increases with purchases of additional land, the rise in land values outstrips the increase in debt. Furthermore, more rapid expansion of the farm using debt financing is not possible because the operator is required to have sufficient cash to pay 25% of the purchase price of a 40-acre tract of land plus the necessary fixed complement of other production assets before expansion can occur. So the cash flow and down-payment requirements limit acquisitions even though additional debt could be obtained. By the fifteenth year, the growth rate appears to have stabilized around 16.7% per year. Family living expenditures reach approximately $25,000 in current dollars (approximately $11,000 in real terms) after having been at less than $10,000 per year for the first nine years of the analysis.[7]

The 320-acre farm is able to expand its acreage base during the fifteen years of simulation as indicated in table 3. Approximately 40 additional acres of land are added to the 320-acre farm in the sixth period of the analysis, and by the fifteenth year acreage has increased to 564 acres. Total equity has increased to $3,974,927 by the fifteenth year for this farm, and the debt-to-asset ratio has declined from 50% to slightly less than 15% during this period. Note that the debt-to-asset ratio decreases more slowly for the 320-acre unit compared to the smaller firm, primarily because it is acquiring more incremental acreage compared to the smaller unit.

The support price program enables the larger high-equity farm (Farm C) to more than double its acreage during the fifteen-year simulation. Acreage increases from 640 acres in the first period to 1314 acres by the fifteenth year, and the debt-to-asset ratio has declined to .133. Note that family living for this farm is always in excess of $30,000 in current dollars, and increases to $128,215 ($56,710 in real terms) by the fifteenth year.

Thus, the government support price program enables the larger, higher equity farm to expand more rapidly than the smaller, highly leveraged unit in terms of the land base. Rate of growth in net worth is not significantly different between the three farms, but the level of family living is also higher for the larger unit. In essence, the support price program improves the guaranteed cash flow of the larger compared to the smaller unit, and this combined with the lower debt-servicing requirement and larger amount of uncommitted cash from current land holdings enables the larger, higher equity farmer to expand his land base more rapidly, pay a higher price for the land, and enjoy a higher level of consumption and family living.

[7] Estimates of financial variables in real terms are obtained by deflating current values by the assumed 6% annual rate of inflation.

The Impact of Leverage

One possible explanation for the differences in expansion rates and financial growth between the large, high-equity and small, low-equity farms summarized earlier might be the initial equity position and debt-servicing obligation rather than farm size. Table 4 summarizes the financial characteristics and growth of the firm assuming all three units have initial debt-to-asset ratio of .30 and .70. Note that with a 30% debt-to-asset ratio, the smaller unit expands its land acreage from 160 to 407 acres (a 154% increase), and increases its net worth to approximately $2,859,911 by year fifteen. The consumption level increases from $14,172 in year one to $40,821 in the fifteenth year. In contrast, the two larger farms increase their acreage by approximately 100% by year fifteen with an initial debt to asset ratio of 30%; but the growth rate in net worth is only slightly less than that of the smaller farm with the same leverage ratio. With a debt-to-asset ratio of 70% for all three farms, the 640-acre unit is able to expand its acreage whereas the 320- and 160-acre units do not generate sufficient funds to expand. The rate of growth in equity is about the same for all three farms, but the consumption level for the larger unit is almost double that of the two smaller farms. Thus, with a high leverage ratio for all farms, the support price program appears to enhance the growth potential and the standard of living or consumption level of the larger compared to the smaller units. With the low leverage ratios, the smaller unit expands its land base more rapidly in relative terms, but the larger units acquire significantly more acreage in absolute terms and exhibit higher levels of family living expenditures as well.

The financial implications of the government program for a firm of constant size with different leverage ratios are also illustrated in table 4. For example, with a 70% initial debt to asset ratio, the 640-acre farm can expand to only 682 acres by the fifteenth year; family consumption is $50,510 per year ($24,998 in real terms) and net worth has increased to $4.8 million in year fifteen. In contrast, with a 30% initial debt to asset ratio, the 640-acre farm expands to 1314 acres by year fifteen, with a family living of $128,215 ($56,710 in real terms) and a net worth of $9.2 million in that year. Similar differences in growth are exhibited by the two smaller firms as a function of leverage. These comparisons clearly illustrate the guaranteed cash flow benefits of a cost-of-production-indexed price support program which accrue to those units that have a lower initial leverage ratio, with the result that such firms exhibit more rapid rates of growth in land acquisition and net worth accumulation.

The Impact of Government Program Parameters

The impact of alternative mandated returns to land included in the cost-of-production calculations for the government price support program is indicated in table 5. Note that by the fifteenth year, the support price has increased from $2.10 to $4.58 with a 3.5% land return included in the cost of production compared to an increase from $2.10 to $3.03 with a 1.5% land return. The bid price for land is approximately $4,700 to $4,900 higher for all three units with the higher mandated land return. The larger, higher-equity units have higher bid prices under either the 1.5% or 3.5% land-return assumption, so would tend to be more successful bidders in the real estate market. Note that the lower bid prices for land with the

Table 4. Sensitivity to the Initial Equity Position and Debt Servicing Obligation of the Firm, by Farm Situation

		30% Debt/Asset Ratio			70% Debt/Asset Ratio		
Item	Unit	Farm A	Farm B	Farm C	Farm A	Farm B	Farm C
Support price level	$/bu.	4.58	4.58	4.58	4.58	4.58	4.58
Capitalization rate of land	%	2.67	2.81	3.06	2.48	2.55	2.73
Bid price for land	$/ac.	7,323	7,677	8,123	7,092	7,403	7,867
Acres owned by the firm	acres	407	694	1,314	160	320	682
Total assets	$1000	3,372	5,711	10,643	1,435	2,685	5,670
Total liabilities	$1000	512	745	1,411	209	391	860
Equity	$1000	2,860	4,966	9,232	1,226	2,293	4,809
Annual growth in equity	%	16.66	15.70	15.23	16.66	16.20	16.53

Note: Results are drawn from year fifteen of the simulation.

Table 5. Sensitivity to the Return of Land Mandated in the Cost of Production by the Government Price Support Program

		Farm A		Farm B		Farm C	
Item	Unit	1.5%	3.5%	1.5%	3.5%	1.5%	3.5%
Support price level	$/bu.	3.03	4.58	3.03	4.58	3.03	4.58
Capitalization rate of land	%	2.19	2.49	3.10	2.73	3.98	3.06
Bid price for land	$/ac.	2,418	7,092	2,868	7,588	3,204	8,123
Acres owned by the firm	acres	208	160	702	564	1,491	1,314
Total assets	$1000	768	1,435	2,291	4,655	4,801	10,643
Total liabilities	$1000	294	209	809	680	1,295	1,412
Equity	$1000	474	1,226	1,482	3,975	3,506	9,232
Annual growth in equity	%	10.33	16.66	9.88	16.46	8.78	15.23
Consumption	$	11,305	24,860	11,389	49,324	66,177	128,215

Note: Results are drawn from year fifteen of the simulation.

1.5% land return enable all three firms to increase their land base compared to the 3.5% return program alternative. The rate of growth in equity declines by approximately 6.25% to 6.50% for all three farms when the mandated return is reduced from 3.5% to 1.5%, primarily because of the lower rate of increase in land values. Consumption expenditures are reduced significantly for all farms because of lower commodity prices with a lower land return, but the two smaller units are impacted more by this reduction in family living expenditures with consumption totaling approximately $11,000 ($5,000 in real terms) in the fifteenth year. So the lower mandated return enables all farms to expand their land base more rapidly, but the larger, higher equity firm can still bid more for land and acquire more land resources compared to the smaller, high-leveraged unit. Furthermore, the larger unit also maintains a significantly better standard of living with the lower mandated return to land included in the support price program.

The implications of different rates of cost protection through the support program are illustrated in table 6. For example, if the support price program only covers 80% of the cost of production, the support price in year fifteen is only $2.94 compared to a $8.22 support price if 100% is covered. The implications of different cost protection percentages for land prices are also clearly illustrated by the data in table 6. Land values in year fifteen are in the $18,000–$20,000 range if 100% of the cost of production is supported by the government program compared to $2,000–$3,000 if only 80% of production costs are covered by the support price program. The financial consequences of alternative rates of coverage are also apparent from table 6. For the small, highly leveraged farm, the rate of annual growth in equity accumulation increases from 8.77% per year with the 80% coverage to almost 23% per year with the 100% coverage. Equity accumulation by year fifteen increases from $375,489 to $3,166,838 with shifts in the government program from 80% to 100% coverage. In similar fashion, the rate of equity

Table 6. Sensitivity to the Percentage of the Costs of Production Supported by the Government Price Support Program

		Farm A			Farm B			Farm C		
Item	Unit	80%	90%	100%	80%	90%	100%	80%	90%	100%
Support price level	$/bu.	2.94	4.58	8.22	2.94	4.58	8.22	2.94	4.58	8.22
Capitalization rate of land	%	2.24	2.48	2.61	3.35	2.73	2.60	4.39	3.06	2.72
Bid price for land	$/ac.	2,031	7,092	18,445	2,499	7,588	18,983	2,835	8,123	20,003
Acres in farm	acres	160	160	160	675	564	320	1,506	1,314	1,091
Total assets	$1000	585	1,435	3,376	1,978	4,655	6,702	4,296	10,643	21,700
Total liabilities	$1000	209	209	209	751	680	280	1,293	1,411	1,839
Equity	$1000	375	1,226	3,167	1,227	3,975	6,422	3,003	9,232	19,861
Annual growth in equity	%	8.77	16.66	22.99	8.62	16.46	19.66	7.74	15.23	20.34

Note: Results are drawn from year fifteen of the simulation.

accumulation for the two larger firms also increases dramatically as the coverage increases from 80% to 100%.

Alternative rates of coverage also influence the rate of land acquisition for the various farms. With 80% cost protection, the larger farm is able to expand from 640 to 1506 acres, whereas with 100% cost protection the land base only expands to 1091 acres. This difference in rate of land acquisition is primarily attributable to the differences in land prices. With a lower level of cost protection, the price of land is not bid up as rapidly and more acres can be acquired early in the planning horizon, thus providing a financial base for more rapid expansion. In contrast, with 100% cost protection, land values increase rapidly and the firm does not have sufficient liquidity to make land purchases. Note that irrespective of the level of cost protection, the smaller, highly leveraged unit is unable to activate any land purchases during the planning horizon. So land values, financial growth, and equity accumulation are sensitive to the percentage of the cost-of-production guarantee included in the government program. In addition, the benefits in terms of land acquisition are larger for the large, high-equity unit compared to the small, low-equity unit, irrespective of the level of cost protection.

The sensitivity of the results to different rates of inflation in prices also was analyzed. The initial set of assumptions included a 2% rate of inflation for expected corn prices (i.e., the mean of the original price distribution unmodified by any support program); the alternative rate of 4% was also analyzed. A higher rate of inflation in expected "market" prices lessens the impact, or "effectiveness," of the price support program over time. With a higher inflation rate, the price distribution is more slowly truncated by the cost-of-production-fed price support program. In general, however, the inflation rate assumption has much less effect on the bid prices, land values, and financial growth than the other model parameters.

Conclusions and Implications

Recent proposals to index government support prices based on the cost of production will have a significant impact on the agricultural sector. The results summarized here indicate that with current price expectations and government program parameters and conservative inflation rates, the cost-of-production-based support price mechanism could increase land prices dramatically within a short period of time. Although all current land owners receive the benefit of the capital gain that would result, the larger, high-equity operator is best able to pay the higher price for additional land. Furthermore, the guaranteed cash flow that results from such a support price program is much greater for the larger, high-equity farmer—so he can utilize more debt to acquire the land and service the debt without impairing his consumption level. Thus, the great majority of the benefits of such a program go to larger, high-equity producers.

The numerical results clearly suggest that the financial characteristics of the firm as well as the size of the firm are important in evaluating the micro impacts and structural implications of government support price programs. In general, highly leveraged firms will receive fewer benefits of a cost-of-production indexed price support program relative to firms with lower leverage ratios, with the result that lower leveraged (higher equity) firms will grow more rapidly in terms of net worth and land ownership as well as exhibit higher levels of family living.

The implications for policy analysis and distributional impact studies as well as data collection are apparent. Evaluating a policy change without an analysis of the impacts on firms with different financial characteristics as well as different sizes in terms of gross sales, acres, etc., will provide only an incomplete picture of the distribution of costs and benefits. Furthermore, classification of firms by capitalization structure (debt-equity ratio) may be equally as important as size classification (gross sales) in collecting and analyzing data such as that obtained in the Census of Agriculture for policy impact analysis.

[*Received June 1978; revision accepted November 1978.*]

References

Boxley, Robert F., and William D. Anderson. "The Incidence of Benefits from Commodity Price Support Programs: A Case Study of Tobacco." *Government Spending and Land Values*, ed. C. Lowell Harriss, pp. 79–103. Madison: University of Wisconsin Press, 1973.

Boxley, Robert, Jr., and W. L. Gibson, Jr. "Peanut Acre-

age Allotments and Farm Land Values." University of Virginia Agr. Exp. Sta. Tech. Bull. No. 175, Blacksburg, Sept. 1964.

Gardner, B. Delworth, and Rulon D. Pope. "How Is Scale and Structure Determined in Agriculture?" *Amer. J. Agr. Econ.* 60(1978):295–302.

Harris, Duane G. "Inflation-Indexed Price Supports and Land Values." *Amer. J. Agr. Econ.* 59(1977):489–95.

Hedrick, James L. "The Effects of the Price-Support Program for Peanuts on the Sale Value of Farms." *J. Farm Econ.* 44(1962):1749–53.

Krenz, Ronald D. "Current Efforts at Estimation of Costs of Production in ERS." *Amer. J. Agr. Econ.* 57 (1975):929–33.

Lee, Warren F., and Norman Rask. "Inflation and Crop Profitability: How Much Can Farmers Pay for Land?" *Amer. J. Agr. Econ.* 58(1976):984–90.

Penn, J. B., and W. H. Brown. "Target Price and Loan Rate Concepts for Agricultural Commodities." *Agricultural-Food Policy Review.* USDA ERS AFPR-1, Jan. 1977.

Reynolds, John E., and John F. Timmons. "Factors Affecting Farmland Values in the United States." Iowa State University Agr. Exp. Sta. Bull. 566, Feb. 1969.

Scott, John T., Jr. "Returns to Corn-Soybean Farms by Size of Unit and Implications for Land Values." *Returns to Land in the Corn Belt, Government Crop Price Guarantees Based on Cost of Production and Land Values.* Dep. Agr. Econ. 4448, University of Illinois, Aug. 1977.

Sharples, Jerry A., and Ronald Krenz. "Cost of Production: A Replacement for Parity?" *Agricultural-Food Policy Review.* USDA ERS AFPR-1, Jan. 1977.

Tweeten, Luther G. *Foundations of Farm Policy.* Lincoln: University of Nebraska Press, 1970.

Vickers, Douglas. *The Theory of the Firm: Production, Capital, and Finance.* New York: McGraw-Hill Book Co., 1968.

A Quarterly Econometric Model of United States Livestock and Feed Grain Markets and Some of Its Policy Implications

Enrique R. Arzac and Maurice Wilkinson

This paper discusses the structural equations, forecasting properties, dynamic characteristics, and economic policy implications of a quarterly econometric model of U.S. livestock and feedgrain markets. Quarterly, semi-annual, and annual endogenous variables are incorporated by allowing individual structural equations to be estimated and to enter into the solution of the model with different periodicities. Commodity prices are determined by market equilibrium conditions rather than by autoregressive and other time-series techniques. Dynamic multipliers give the effect of changes in corn exports, beef imports, government grain stocks, corn yield, consumer income, and the support price for corn on producer and retail prices and acreage planted.

Key words: econometric model, economic policy, U.S. agriculture.

This paper presents a quarterly econometric model of the United States livestock and feed grain markets and analyzes some of its policy implications. The econometric model is designed to provide quarterly forecasts for such variables as livestock and grain production and prices, the retail-producer price spreads for meat products, and consumer demand for meat. The forecasts are conditional upon assumed values of such exogenous variables as disposable personal income, government policy with respect to the livestock and feed grain markets, and certain other developments in the economy.

Some of the principal features of the model are as follows: Quarterly, semiannual, and annual endogenous variables are incorporated by allowing individual structural equations to be estimated and to enter into the solution of the model with different periodicities. Thus the endogenous annual corn harvest enters into the solution of the model only in the fourth quarter of each year. Feed grain production, consumption, and prices are endogenous so that the dynamics of the interaction of the livestock and feed grain markets may be analyzed.[1] The microeconomic market supply and demand specification is retained as far as possible. Commodity prices are determined by market equilibrium conditions rather than by autoregressive and other time-series techniques.

The organization of this paper is as follows. The second section discusses the estimated structural equations; the third analyzes the solution of the model and evaluates its forecasting accuracy; the fourth examines dynamic characteristics and utilizes the multipliers of the model to analyze a number of policy issues; and, finally, the fifth section summarizes the main findings of the paper.

The Structural Equations

The econometric model consists of forty-two equations of which five are market clearing equations and fourteen are identities. These equations explain the demand and supply for five commodities (fed and nonfed beef, pork, chicken, and the principal feed grain—corn)

The authors are associate professor and professor, respectively, at the Graduate School of Business, Columbia University.

The authors gratefully acknowledge financial support from the C. W. Cook Center for Food Policy Studies of Columbia University and valuable comments from Giulio Pontecorvo and *Journal* referees.

[1] The most complete econometric study of the livestock sector is that of Freebairn and Rausser. However, their model is annual and treats grain prices as exogenous. Previous studies focusing on partial aspects of the livestock sector are Crom, Hayenga and Hacklander, and Langemeier and Thompson. Meilke modeled the grain sector. Models of the Canadian livestock sector are Kulshreshtha and Wilson and Tryfos. Aggregate models of the U.S. agriculture focusing on its interrelation with the rest of the economy but not developing the livestock production process include Fox and Chen.

and the role of prices in clearing the market for each commodity.

Table 1 identifies variables and table 2 presents the estimated structural equations.[2] In addition, measures of the goodness of fit and serial correlation of the residuals, the estimator utilized, the sample period, and the periodicity of the equation are listed. Some equations are estimated annually (10) and (11) or semiannually (16) due to data limitations, while other structural equations represent decisions or events that essentially occur only annually—see (22) and (23) dealing with planting and harvesting of grain. Structural equations not characterized by simultaneous determination of endogenous variables are estimated by ordinary least squares and all other equations by (truncated) two-stage least squares (Fair 1970, 1973). The list of instrumental variables is given in the notes to table 2.

A linear functional specification has been adopted for the structural equations of the model. The primary justification for this structure is the desire to simplify the data requirements, estimation, and analysis of the model (Arzac and Wilkinson). Dummy variables are introduced in quarterly demand and supply equations to allow for seasonal effects such as holidays and weather on demand (Logan and Boles) and biological growth patterns of livestock on supply. Explanatory variables with the expected signs have been retained in the structural equations even when the estimated standard errors are large relative to the point estimate of the coefficient.

The structural equations may be arranged into the following blocs:

Bloc	Equation Numbers
I. Consumer demand for meat	(1)–(4)
II. Retail and producer price relations	(5)–(8)
III. Livestock production, inventory, and supply relations	(9)–(19)
IV. Demand and supply of feed grain	(20)–(23)
V. Market clearing equations and identities	(24)–(42)

[2] The data were obtained from the following sources: USDA *Livestock and Meat Statistics, Feed Situation, Livestock and Meat Situation, Hogs and Pigs, Agricultural Statistics, Poultry and Egg Situation, Crop Production*, and worksheets; U.S. Department of Commerce, *Business* and *Employment and Earnings*.

Table 1. Variable Definitions

Endogenous Variables

*AP*1	Acreage planted for corn (thou. a.)	*Mi*	Retail-producer price spread, $i = 1, \ldots, 4$ (¢/cwt.). See equ. (23)–(27).
AU	Animal units on feed (m. hd.)	*PFi*	Producer price of meat, $i = 1, \ldots, 4$ (¢/cwt.)
DSC	Change in prior calf slaughter, see equ. (29)	*PF*5	Price of feeder steers (¢/cwt.)
*EC*4	Prior exports of corn, see equ. (32)	*PG*1	Corn price (¢/10 bu.)
ICC	Commercial corn inventory, end of per. (m. bu.)	*PRi*	Retail price of meat, $i = 1, \ldots, 4$ (¢/100 lb.)
IH	Number of pigs on feed, end of period (thou. hd.)	*SC*	Calves slaughtered (thou. hd.)
IP	Cattle and calves on feed, end of period (thou. hd.)	*SC*4	Prior calf slaughter, see equ. (28)
*IP*4	Prior placement of cattle and calves on feed, see equ. (30)	*XDC*	Domestic corn demand (m. bu.)
KB	Inventory of beef cows, begin. of period (thou. hd.)	*XDi*	Demand for meat, $i = 1, \ldots, 4$ (m. lb.)
KC	Net calf crop (thou. hd.)	*XSi*	Meat production, $i = 1, \ldots, 4$ (m. lb.)
KH	Sows kept for breeding, begin. of period (thou. hd.)	*XSC*	Corn production (m. bu.)
		YZ	Real disposable personal income ($10 mill. 1967) See equ. (42).
		Zi	Real retail price of meat, $i = 1, \ldots, 4$ (¢ of 1967/100 lb.). See equ. (38)–(41).

Exogenous Variables

*B*1	Choice beef by-product allowance (¢/10 cwt.)	*KD*	Inventory of dairy cows, begin. of period (thou. hd.)
*B*3	Pork by-product allowance (¢/10 cwt.)	*LP*	Index of productivity in poultry production (1967 = 1000)
CPI	U.S. consumer price index (1967 = 10,000)	*PF*	Support price for corn (¢/10 bu.)
EC	Export of corn (m. bu.)	*PSB*	Price of soybean (¢/10 bu.)
EXi	Exports of meat, $i = 1, \ldots, 4$ (m. lb.)	*Qi*	Dummy variable, $i = 2, 3, 4$. $Qi = 1000$ in *i*th quarter, $Qi = 0$ otherwise
H	Corn yield per harvested acre (bu./100 a.)	*W*	Wage rate in meat packing ($/100 w.)
ICG	Government corn inventory, end of period (m. bu.)	*W*2	Wage rate in poultry dressing ($/100 w.)
ID	Dairy herd replacements, begin. of period (thou. hd.)	*Y*	Current disposable personal income ($ 10 mill.)
IMXi	Imports of meat, $i = 1, \ldots, 4$ (m. lb.)		

Meat Commodity Index: $i = 1$ for fed beef, $i = 2$ for nonfed beef, $i = 3$ for pork, $i = 4$ for chicken.

Total consumer demand for the four meat commodities (XDi) is assumed to be a function of the real price of each commodity (Zi) and real disposable personal income (YZ). The consumer demand equations (1)–(4) exhibit theoretically plausible and statistically significant coefficients for own price and income.[3] Five of the twelve cross-price coefficients are negative, which would violate a priori belief that these four commodities are pairwise specific or net substitutes (Theil, p. 41). The econometric evidence, however, is not consistent (e.g., Christensen and Mancer, p. 47, and Freebairn and Rausser).

The second bloc of equations specifies the relationship between the consumer or retail prices of meat as a markup or margin model (George and King, Fox). Labor costs (W) and the by-product value of the respective commodity (Bi) explain a significant part of the difference between retail and producer prices (Mi).

Equations (9)–(19) explain livestock production, inventory, and supply. Equation (9) is a partially reduced form equation (Nerlove) in which the price of feeder steers ($PF5$), an important input in beef production, is determined by the producer prices of fed ($PF1$) and nonfed beef ($PF2$), feed grain ($PG1$), prior calf slaughter (DSC), and the available supply of calves, the net calf crop (KC) minus dairy herd replacements (ID). All estimated coefficients are significant and have the expected sign. $PF5$ is more responsive to $PF2$, which represents the current opportunity cost of feeding, than to $PF1$, which is only an indicator of the future price of fed beef. The supply side is modeled in terms of undeflated prices. Given the relatively modest inflation rate observed during most of the sample, deflating by any of the available general indexes would induce unacceptable errors in variables.

Equation (10) explains the inventory (herd) of (breeding) beef cows (KB) as a function of the prices of feeder calves and nonfed beef and the previous inventory. Although the price coefficients have the expected signs, the standard errors are relatively large and it is clear that the lagged dependent variable is the major explanatory variable. Equation (11) determines the net calf crop (KC) as proportional to the inventory of beef and dairy herds. Calf slaughter takes place from both beef and dairy herds. Equation (12) indicates that calf slaughter (SC) varies inversely with the price of feeder steers and directly with the inventory of dairy cows.

The placement of cattle on feed (IP) is assumed in equation (13) to depend upon the prices of fed beef and feed grain and cattle available for placement [$SC4$ and $KC(-4) - ID$]. The inclusion of lagged placements as an explanatory variable reflects the partial adjustment of placements given the uncertainty of prices. All estimated coefficients are significant and have the expected signs. In equation (14) fed beef supply ($XS1$) is positively related to its own price, inversely related to the price of feed grain, and positively related to cattle placed on feed six months previously [$IP(-2)$]. The large standard error on $PF1$ indicates that in our quarterly model the own-commodity price has the principal impact upon decisions taken earlier in the production process—the supply and demand of feeder calves, equations (9)–(10) and (12), and the placement of cattle on feed, equation (13). Finally, the supply of nonfed beef ($XS2$) is explained in (15) as a function of $PF5$, culls from a weighted average of beef and dairy herds ($KB + 0.56KD$) (Freebairn and Rausser, p. 680), the supply of calves available for feeding on grass or feedlots [$KC(-4) - ID$] in conjunction with those placed on feed ($IP4$).

Equations (16)–(20) explain pork and chicken production. Equation (16) explains the partial adjustment of the inventory of breeding sows (KH) in response to the price of feed grain, producer price of pork ($PF3$), and the producer price of fed beef. The latter is often an alternative activity to pork production on

[3] Demand equations (1)–(4) imply the following elasticities at sample means:

	Own price	Income
Fed beef	−1.86	1.02
Nonfed beef	−2.97	.45
Pork	−.87	.65
Chicken	−.98	.52

Freebairn and Rausser report much smaller price elasticities for beef, higher income elasticity for fed beef, and negative income elasticity for nonfed beef. On the other hand, Christensen and Manser report price elasticities for aggregate beef of the same order of magnitude as our disaggregated elasticities and George and King found very small income elasticities for aggregate beef. Our estimates of the own-price elasticities are large because of the high degree of substitution existing between these commodities. Assuming that the ratio of fed to nonfed beef prices is constant and taking into account the cross-price coefficients of equations (1)–(2) we obtain:

	Own price	Income
Aggregate beef	−0.39	0.86
Fed beef	−0.49	1.02
Nonfed beef	−0.12	0.45

Table 2. Econometric Model of the U.S. Grain and Livestock Markets

I. Consumer Demand for Meat

1. $XD1 = 3421 - 0.6439Z1 + 0.7252Z2 - 0.0763Z3 - 0.3058Z4 + 0.2388YZ - 0.0564Q2 - 0.1089Q3$
(605) (0.129) (0.123) (0.076) (0.140) (0.034) (0.063) (0.066)
$- 0.2550Q4$
(0.069)
$S/M = 0.06$, $DW = 0.49$, 2SLS – 1957I/75IV (quarterly)

2. $XD2 = -193 + 0.5497Z1 - 0.8768Z2 + 0.1838Z3 - 0.0109Z4 + 0.0588YZ + 0.0659Q2 + 0.3036Q3$
(729) (0.156) (0.148) (0.092) (0.169) (0.041) (0.076) (0.079)
$+ 0.2684Q4$
(0.083)
$S/M = 0.13$, $DW = 0.45$, 2SLS – 1957I/75IV (quarterly)

3. $XD3 = 2698 - 0.03311Z1 + 0.1451Z2 - 0.3676Z3 + 0.07382Z4 + 0.1486YZ - 0.1184Q2 - 0.0566Q3$
(220) (0.048) (0.045) (0.027) (0.051) (0.0123) (0.023) (0.024)
$+ 0.1630Q4$
(0.025)
$S/M = 0.02$, $DW = 1.50$, 2SLS – 1957I/75IV (quarterly)

4. $XD4 = 941 - 0.03316Z1 + 0.1432Z2 + 0.1104Z3 - 0.3882Z4 + 0.06106YZ + 0.1881Q2 + 0.1968Q3$
(261) (0.046) (0.053) (0.033) (0.081) (0.017) (0.024) (0.025)
$- 0.02509Q4$
(0.027)
$S/M = 0.04$, $DW = 1.50$, 2SLS – 1960I/75IV (quarterly)

II. Retail and Producer Price Relations

5. $M1 = 66.7 + 0.5989PR1 + 0.0645W - 0.0297B1$, $S/M = 0.02$, $DW = 1.32$, OLS – 1957I/75IV
(58.4) (0.028) (0.012) (0.017) (quarterly)

6. $M2 = -152.4 + 0.6999PR2 + 0.0351W - 0.0728B1$, $S/M = 0.05$, $DW = 0.33$, OLS – 1957I/75IV
(100.2) (0.068) (0.019) (0.034) (quarterly)

7. $M3 = 540.9 + 0.5750PR3 + 0.0433W - 0.0911B3$, $S/M = 0.03$, $DW = 0.89$, OLS – 1957I/75IV
(67.6) (0.032) (0.010) (0.026) (quarterly)

8. $M4 = 474.6 + 0.4443PR4 + 0.0045W2$, $S/M = 0.02$, $DW = 1.54$, OLS – 1957I/75IV
(45.5) (0.013) (0.0005) (quarterly)

III. Livestock Production, Inventory and Supply Relations

9. $PF5 = 365.7 + 0.2014PF1 + 1.4034PF2 - 0.1665PG1 + 0.2433DSC - 0.01371(KC(-4)-ID) - 0.1035Q2$
(188.1) (0.072) (0.089) (0.044) (0.109) (0.0062) (0.035)
$- 0.1079Q3 + 0.0816Q4$
(0.034) (0.035)
$S/M = 0.04$, $DW = 0.92$, 2SLS – 1957I/75IV (quarterly)

10. $KB = -900.4 + 1.860PF5(-1) + 0.7133PF5(-2) - 2.285PF2(-1) + 0.9758KB(-1)$
(905.6) (1.514) (0.3048) (2.396) (0.043)
$S/M = 0.02$, $DH = 1.39$, OLS – 1956/75 (annual)

11. $KC = 0.8396(KB + KD)$, $S/M = 0.04$, $DW = 0.33$ (with intercept), OLS – 1956/75 (annual)
(0.0073)

12. $SC = 519.3 - 0.2227PF5 + 0.1060KD(-4) - 0.186Q2 - 0.053Q3 + 0.059Q4$
(260) (0.048) (0.009) (0.071) (0.071) (0.071)
$S/M = 0.14$, $DW = 0.23$, 2SLS – 1957I/75IV (quarterly)

13. $IP = -1643.3 + 0.4702PF1 - 1.073PG1 - 0.1455SC4 + 0.1468(KC(-4)-ID) + 0.6793IP(-1) - 0.6041Q2$
(956.5) (0.118) (0.146) (0.058) (0.032) (0.066) (0.118)
$- 0.1858Q3 + 2.2053Q4$
(0.152) (0.174)
$S/M = 0.04$, $DH = 0.50$, 2SLS – 1958I/1975IV (quarterly)

14. $XS1 = 918.2 + 0.0223PF1 - 0.1082PG1 + 0.3161IP(-2) - 0.6852Q2 - 0.6107Q3 - 0.2751Q3$
(93.1) (0.055) (0.560) (0.010) (0.059) (0.057) (0.056)
$S/M = 0.05$, $DW = 1.02$, 2SLS – 1957I/75IV (quarterly)

15. $XS2 = -2507.1 - 0.1625PF5 + 0.0670(KB + 0.56KD) + 0.0770(KC(-4)-ID) - 0.1570IP4 + 0.085Q2$
(285.5) (0.038) (0.011) (0.018) (0.016) (0.051)
$+ 0.302Q3 + 0.317Q4$
(0.051) (0.051)
$S/M = 0.11$, $DW = 0.97$, $2SLS$ – 1957I/75IV (quarterly)

16. $KH = 6089 - 0.9080PG1(-2) + 0.5862PF3(-2) - 0.2789PF1(-2) + 0.3891KH(-1) + 0.351Q3$
(1614) (0.297) (0.310) (0.331) (0.174) (0.213)
$S/M = 0.06$, $DH = 1.45$, OLS – 1964II/75IV (semiannual)

17. $IH = -4471 + 1.052PF3(-1) - 1.567PG1(-1) + 1.624KH + 0.6676IH(-1) + 8.519Q2 + 5.397Q3$
(3605) (0.356) (0.471) (0.484) (0.111) (0.772) (0.539)
$+ 3.285Q4$
(0.552)
$S/M = 0.03$, $DH = 1.63$, OLS – 1964I/75IV (quarterly)

18. $XS3 = -1271.7 + 0.1489PF3 + 0.09047IH(-1) + 0.333Q2 - 0.409Q3 + 0.051Q4$
(655.7) (0.039) (0.0129) (0.110) (0.087) (0.087)
$S/M = 0.07$, $DW = 0.48$, $2SLS$ – 1962III/75IV (quarterly)

19. $XS4 = 77.5 + 0.09159PF4(-1) - 0.07762PG1(-1) + 0.3920LP + 0.06526XS4(-1) + 0.2247Q2 + 0.1102Q3$
(67.5) (0.028) (0.019) (0.122) (0.011) (0.017) (0.028)
$- 0.0622Q4$
(0.031)
$S/M = 0.03$, $DH = 0.31$, OLS – 1960II/75IV (quarterly)

IV. Demand and Supply of Feed Grain

20. $XDC = 96.6 + 0.0261AU - 0.0160PG1 + 0.0174Y2 - 0.1090Q2 - 0.2413Q3 + 0.2259Q4$
(130.3) (0.0085) (0.0360) (0.0170) (0.043) (0.043) (0.046)
$S/M = 0.10$, $DW = 2.27$, $2SLS$ – 1962II/75IV (quarterly)

21. $PG1 = 529.9 - 0.1730ICC + 0.7094PG1(-1) + 0.6167EC4 - 0.1491Q2 - 0.2739Q3 + 0.1037Q4$
(192.5) (0.073) (0.067) (0.137) (0.080) (0.139) (0.101)
$S/M = 0.10$, $DH = -.76$, $2SLS$ – 1957I/75IV (quarterly)

22. $AP1 = 51229 + 14.007PF + 5.042PG1(-1) - 0.6035PSB(-1)$, $S/M = 0.02$, $DW = 1.88$, OLS – 1961/75
(2899) (4.960) (1.031) (5.202) (annual)[a]

23. $XSC = -4280 + 0.060AP1 + 0.614H$, $S/M = 0.02$, $DW = 2.26$, OLS – 1957/1975
(274) (0.003) (0.013) (annual)

V. Market Clearing Equations and Identities

23+i. $Mi = PRi - PFi$, $i=1, \ldots, 4$

28. $SC4 = \sum_{t=0}^{3} SC(-t)$

29. $DSC = SC4 - SC4(-1)$

30. $IP4 = \frac{1}{4} \sum_{t=0}^{3} IP(-t)$

31. $AU = 1.523IP(-1) + 0.2285IH(-1) + 0.0702XS4$[b]

32. $EC4 = \sum_{i=0}^{3} EC(-i)$

33. $XSC = XDC + ICC + ICG - ICC(-1) - ICG(-1) + EC$

33+i. $XDi + EXi = XSi + IMXi$, $i = 1, \ldots, 4$

37+i. $Zi = PRi/CPI$, $i = 1, \ldots, 4$

42. $YZ = Y/CPI$

Note: Standard errors are in parentheses. S/M is the ratio of the standard error of the equation to the mean of the dependent variable. DW is the Durbin-Watson statistic. DH is the simple Durbin H statistic [Durbin (1970)]. The basic set of instruments for $2SLS$ is YZ, CPI, W, $B1$, $B2$, $W2$, $KD(-4)$, LP, EC, PF, H, $Q2$, $Q3$, $Q4$. Lagged endogenous variables appearing in a particular equation are added to the basic set when estimating that equation.

[a] Lags indicate the quarter previous to planting.

[b] Grain-consuming animal units. See USDA (1974), p. 94.

small farms; however, the standard error is large on this variable. The partial adjustment of placement of pigs on feed (*IH*) is specified in equation (17) as a function of the prices of pork and feed grain and the inventory of breeding sows. Equation (18) indicates that the supply of pork is dependent upon its own price and prior placements of pigs on feed. Finally (19) specifies the supply of chicken as a function of its own price, the price of feed grain, an index of productivity in the poultry sector, and lagged supply of chicken. All variables are significant and exhibit the expected signs.

Equations (20)–(23) explain the demand for and supply of corn. Equation (20) explains the domestic demand for corn (*XDC*) for animal feeding and food processing as a function of the number of grain consuming animal units [see equation (32) and U.S. Department of Agriculture 1974, p. 91] on feed, real personal disposable income, and its own price. Omitting other feed grains seems an acceptable approximation. Corn accounts for more than 75% of the feed grain market. Moreover, the close substitutability between the different feed grains keeps the relative prices within close bounds. For example, during 1957–75, the coefficients of correlation of the price of corn with the price of sorghum, barley, and oats were 0.98, 0.97, and 0.81, respectively. Also the correlation between the prices of corn and soybeans was 0.89 in the same period. Corn exports are treated as exogenous. Its main determinants appear to be income, grain output, and government policy in the rest of the world—variables exogenous to our model. Our analysis of corn exports detected no negative price effect.

Equation (21) assumes the price of corn adjusts according to the size of commercial stocks, the recent evolution of exports, and the time of the year. Inventories are then almost exclusively determined as a residual by the rest of the model. (In a later section, we show that the model performs this task with high accuracy.) The rationale for this specification, rather than the more traditional normalization on stocks as a regressand, has been given by Heien. Essentially, as Working and Tomek and Gray already have pointed out, current stocks are the main determinant of both spot and futures prices of a commodity like corn with continuous storage. Incidentally, this argument also justifies our omission of futures prices.

Equation (22) describes acreage planted for corn production (*AP*1). The coefficients of the support price (*PF*) and the market price of corn are highly significant. The support price for corn is weighted by the restrictions imposed on program participants as in Ryan and Abel. The effect of the price of soybeans (*PSB*) is small and insignificant. This equation was estimated using 1961–75 data only. Pre-1961 data was excluded because in those years farmers could collect payments for corn acreage diversion and plant sorghum instead. This created an artificial sensitivity of corn acreage to diversion payments and sorghum price.[4] The effect of diversion payments on *AP*1 also was analyzed; however, this variable exhibited a positive and insignificant coefficient in the regression with 1961–75 data and is excluded.[5] The price of farm inputs was also tested and excluded because its coefficient was positive and insignificant, presumably because the available price series are too aggregated to be meaningful in the present context. Finally, the supply of corn (*XSC*) is specified in (23) as a function of yield per acre harvested in the fall (*H*) and acreage planted in the spring (*AP*1). Note this is not an identity because not all acreage planted is harvested for grain (part is used as forage or harvested for silage and part is lost due to bad weather). Although (22) and (23) constitute a relatively simple specification of the production of corn, both equations exhibit excellent fit and perform very well in the context of the complete model.

The final bloc of equations in table 2 are the identities and market-clearing equations for the four meat commodities and corn (24)–(42). For fourteen of the twenty-three structural equations in table 2 (1–9, 11–12, 14–15, 18), the hypothesis of zero autocorrelated residuals is rejected at the 5% significance level on the basis of the Durbin-Watson (DW) or Durbin H (DH) statistic. These equations were reestimated with (truncated) two-stage least squares and the ad hoc assumption of first-

[4] We found no substitution in production between sorghum and corn. This is consistent with Houck and Ryan, who found no substitution since 1961. They also note that the substitution between soybeans and corn appears to be much less now than before 1961.

[5] Johnson (1973, pp. 34–35) has pointed out that "since the U.S. Department of Agriculture changes the features of the wheat and feed programs on the basis of anticipated supply and demand conditions, it is very difficult to know how much of the change in acreage seeded was due to diversion and how much was due to farmer response to the same set of supply and demand conditions." This might explain why diversion payments are a redundant regressor. Houck and Ryan report low *t*-values for *PF* and *DP* using 1960–69 data.

order serial correlation or generalized least squares and first-order serial correlation. With both estimators the optimal estimate of the first-order autocorrelation coefficient was obtained with scanning and local iteration (Fair, 1970). Few coefficients in these equations exhibited significant changes. Later in this paper we discuss the insensitivity of the policy implications of the model to autocorrelated residuals. While the low DW statistics probably indicate departures from linearity rather than simple serial correlation, the insensitivity of our results to the latter is reassuring.

Forecasting Accuracy of the Model

Table 3 compares the forecasting accuracy of the econometric model and a fourth-order autoregressive model. The root-mean-squared-error as a fraction of the mean is used as criterion of performance. The first two columns show the goodness of fit during 1965I–1975IV. The econometric model performs better than the autoregressive model for twenty-two out of thirty-two endogenous variables. The performance of the two models in predicting fed beef price is about the same. The autoregressive model does better for nonfed beef and feeder steer prices but worse for pork, chicken, and corn prices.

The last two columns measure the forecasting accuracy of the two models outside the sample. (For this purpose, both models were reestimated excluding 1975 data.) The econometric model performs much better than the autoregressive model. It exhibits smaller errors for twenty-four out of the thirty-two variables and the autoregressive model makes large errors in such key variables as the price of corn (75% versus 6.8%).

The results of dynamic simulation of the

Table 3. Forecasting Accuracy of Econometric Model

Variable	Goodness-of-Fit 1965I–1975IV: Autoregressive Model	Goodness-of-Fit: Econometric Model, Static	Goodness-of-Fit: Econometric Model, Dynamic	*Ex-Post* Forecast 1975I–1975IV: Autoregressive Model	*Ex-Post* Forecast: Econometric Model
	Root Mean Squared Errors as Proportion of Mean				
*PR*1	.048	.050	.104	.062	.071
*PR*2	.047	.088	.168	.086	.135
*PR*3	.070	.059	.109	.114	.053
*PR*4	.100	.054	.128	.143	.051
*PF*1	.094	.077	.133	.140	.099
*PF*2	.093	.132	.196	.377	.320
*PF*3	.156	.081	.152	.218	.053
*PF*4	.148	.091	.181	.230	.074
*PF*5	.079	.112	.205	.377	.164
*PG*1	.127	.096	.138	.746	.068
*Z*1	.043	.046	.118	.054	.069
*Z*2	.039	.073	.172	.112	.132
*Z*3	.061	.054	.105	.177	.057
*Z*4	.085	.049	.118	.058	.049
*XS*1	.053	.048	.056	.187	.056
*XS*2	.121	.087	.231	.356	.073
*XS*3	.081	.034	.078	.164	.024
*XS*4	.035	.033	.032	.047	.023
XSC	.096	.038	.033	.077	.006
*AP*1	.069	.029	.029	.041	.040
*XD*1	.054	.047	.054	.196	.055
*XD*2	.111	.137	.203	.293	.144
*XD*3	.006	.004	.080	.219	.032
*XD*4	.034	.036	.045	.044	.046
XDC	.114	.075	.093	.238	.106
SC	.078	.179	.240	.271	.330
IP	.098	.029	.071	.024	.043
IH	.067	.025	.052	.216	.050
ICC	.181	.050	.146	.242	.031
KH	.060	.030	.062	.186	.073
KB	.015	.020	.041	.012	.053
KC	.034	.046	.044	.050	.041

econometric model during the period 1965I–1975IV are presented in the third column of table 3 (forecasted rather than observed values of the lagged endogenous variables are used in dynamic simulation). As expected, the errors of prices and inventories are larger than in the static solution. This is because of random errors on the endogenous variables which, though not taken into account in dynamic simulation, affect the actual realization of the time series via the dynamic structure of livestock production.

While the above evaluations are biased in favor of the econometric model because of the assumption that the values of the exogenous variables are known (Feldstein), the results suggest that the model provides a reasonable representation of the behavior of the grain-livestock sector which can be used for policy analysis.

Dynamic Multipliers

Expressing the model as a first-order, linear-difference equation system permits testing for stability and studying the dynamic behavior of the model with standard procedures of linear system analysis, Chow, for example.[6] Price responses are expressed in 1975 dollars.

[6] This is accomplished by embedding the structure of the model in an annual format which allows for intrayear nonstationarity due to different equations periodicities and quarterly dummies. The transformation is made writing four annual equations for each semiannual variable. Furthermore, the exogenous price level (*CPI*) which enters nonlinearly in equations (1)–(4) and (38)–(41) is fixed at its 1975IV level.

The model is stable. The characteristic roots of the reduced-form coefficient matrix of lagged endogenous variables all have moduli less than one and there is no borderline case. Moreover, the system exhibits damped cyclical behavior. Cyclical components in the time path of the endogenous variables are contributed by one negative real root and six pairs of complex roots.

Multipliers of Corn Exports

Quarterly exports of corn during 1973–75 were 97 million bushels above their 1972 level. Table 4 presents the effects of changes of this magnitude on market prices and corn acreage. All relative increases are expressed as a percentage of the level prevailing in the fourth quarter of 1975. When subject to a one-quarter 100 million bushel increase in corn exports (23%), the model exhibits a maximum response of 18.9¢ (7%) three quarters later and quickly returns to its preshock level. On the other hand, a permanent increase in exports of the same magnitude has a maximum multiplier of 95.0¢ (36%) after ten quarters, which then declines toward its long-run (steady state) value of 50.2¢ (19%). Most of the adjustment takes place during the first sixteen quarters.

Higher corn prices, in turn, induce upward adjustments in acreage planted and food prices. A one-quarter corn export increase produces transitory increases in meat and chicken prices of 3¢ to 5¢ at the retail level, and of 1¢ to 2¢ at the farm level. A permanent

Table 4. Multipliers of Corn Exports, Nonfed Beef Imports, and Government Inventory of Corn

Endogenous Variable	100 Million Bushel Increase in Corn Exports: Maximum Response to One-Quarter Increase	Permanent Increase: Maximum	Permanent Increase: Long-Term	100 Million Pound Decrease in Beef Imports: Maximum Response to One-Quarter Decrease	Permanent Decrease: Maximum	Permanent Decrease: Long-Term	Maximum Response to 100 Million Bushel Permanent Increase in Corn Stocks
Retail prices (¢/lb.)							
Fed beef	6.67(5)[a]	27.76(9)	7.62	7.39(0)	9.41(1)	.08	1.47(6)
Nonfed beef	4.81(5)	20.77(12)	2.54	8.30(0)	10.16(1)	1.14	1.03(6)
Pork	3.64(6)	25.04(13)	10.76	2.53(0)	2.95(1)	.93	1.19(10)
Chicken	2.72(5)	13.75(11)	5.02	3.15(0)	3.15(0)	.64	.63(7)
Producers prices (¢/lb.)							
Choice steers	2.68(5)	11.13(9)	3.08	2.96(0)	3.77(1)	.03	.59(6)
Utility cows	1.44(5)	6.23(11)	.76	2.49(0)	3.05(1)	.34	.31(6)
Hogs	1.55(6)	10.64(12)	4.60	1.07(0)	1.25(1)	.40	.50(10)
Chickens	1.51(5)	7.64(11)	2.80	1.75(0)	1.75(0)	.36	.35(7)
Feeder steers	2.26(5)	9.29(11)	.74	3.88(0)	4.78(1)	.36	.45(7)
Corn price (¢/bu.)	19.0(3)	95.0(10)	50.2	.7(6)	5.3(14)	3.8	4.5(5)
Acreage (m. acres)	.698(5)	4.702(9)	2.507	.032(5)	.256(17)	.191	.221(5)

[a] The number in parentheses is the delay of the maximum response in quarters.

increase in exports has a long-run effect of 7.62¢ (5.0%) on fed beef, 2.54¢ (2.2%) on nonfed beef, 10.76¢ (7.0%) on pork, and 5.02¢ (7.9%) on chicken prices.

Multipliers of Beef Imports

Table 4 shows that changes in nonfed beef imports have very small, long-run effects on the retail price of nonfed beef (*PR*2) and other meats. This is due to the long-run response of domestic beef supply to price.

Our long-run multipliers for beef imports (table 4, column 7) are of the same order of magnitude as those reported by the Council on Wage and Price Stability (pp. 7–10) and Freebairn and Rausser. Expressed in 1975 prices, the multipliers of a 100 million pound decrease in beef imports reported by the latter authors are .87¢ for fed beef, 1.52¢ for nonfed beef, .13¢ for pork, and .21¢ for chicken at the retail level and about half as large at the farm level. Both of their beef multipliers are slightly larger than ours. This seems to be due to the fact that their model implies a long-run decrease in the inventory of beef cows and in the production of nonfed beef following a permanent decrease in nonfed beef imports (Freebairn and Rausser, pp. 686–87). On the other hand, our model implies that, as one should expect, these two variables increase in the long run.[7]

Multipliers of Government Stocks of Grain

The multipliers of permanent changes in the government stocks of grain are presented in the last column of table 4. A permanent change in the stock of grain can offset in a bushel-for-bushel fashion a temporary change in domestic output. For example, a reduction of ten bushels per acre in corn yield reduces corn output by 614 million bushels [see table 2, equation (23)] and temporarily increases corn prices by 27¢. These changes can be offset by a concommitant decrease of the government stock of corn of the same magnitude. However, government stocks might not be so effective in offsetting price changes due to export fluctuations, because the latter seem to influence prices in two reinforcing ways: through total demand and through price expectations. For example, to offset the effect of a 100-million-bushel, one-quarter increase in corn exports, government stocks should decrease by 420 million bushels. This suggests that stabilization schemes based upon some form of inventory management might not be very effective in dealing with export fluctuations.

Other Multipliers

Table 5 presents the multipliers of corn yield, disposable income, and the support price of corn. A simple measure of their relative importance is presented in table 6, which shows the permanent change in each variable that has the same long-run effects on the retail cost of the 1975 meat basket. Grain exports and beef imports are also included in table 6. Column 2 shows the percentage change in each exogenous variable that results in a 3% change in the retail cost of meat (e.g., a 12.4% increase in corn exports above the 1975 level). Column 3 shows the absolute changes in the respective exogenous variables (e.g., a 55.7-million-bushel increase in corn exports). In order to give an idea of the possible variability of the exogenous variables, column 4 includes their standard deviations in the period 1958–75. The principal conclusion that emerges from this table is that changes in corn exports, corn yields, and consumer disposable income during 1958–75 were mainly responsible for the fluctuations in livestock and feed grain prices. The policy variables—corn price supports and nonfed beef imports—exhibit relatively small multipliers and variability during this period. In particular, table 6 shows that in order to offset the effect of 12.4% increase in corn exports, beef imports would have to increase by about 508.5 million pounds, 119% of their 1975 level. That is, the share of imports in the domestic nonfed beef market would have to increase from 8% to 18%.

Price Effects of the 1977 Farm Bill

Tables 4 and 5 allow us to estimate the likely effects of the 1978 Feed Grain Program and the Grain Reserve Program for 1976 and 1977 grain (USDA 1978, pp. 6, 11, 13). An approximation to the effective support price for corn for 1978, our *PF* variable, is obtained taking 90% of the target price ($2.10/bushel) in order

[7] The long-run multipliers given by our model for a 100 million pound permanent decrease in nonfed beef imports are 30.8, 51.9, −8.0, and 8.6 million pound for fed beef, nonfed beef, pork, and chicken production, respectively. The negative response of pork production is due to the strong effect of the price of corn on breeding and feeding decisions.

Table 5. Multipliers of Corn Yield, Disposable Personal Income, and Corn Support Price

	Decrease in Yield (1 bu./acre)			Increase in Income (1 bill. 1967$)			Decrease in Corn Support (10¢/bu.)		
	Maximum Response to One-Quarter Decrease	Permanent Decrease		Maximum Response to One-Quarter Increase	Permanent Increase		Maximum Response to One-Quarter Increase	Permanent Increase	
Endogenous Variable		Maximum	Long-Term		Maximum	Long-Term		Maximum	Long-Term
Retail prices (¢/lb.)									
Fed beef	.91(9)[a]	2.12(19)	1.15	2.15(0)	2.83(1)	.47	1.24(9)	2.90(19)	1.58
Nonfed beef	.64(9)	1.51(19)	.39	2.02(0)	2.63(1)	.23	.88(9)	2.07(19)	.53
Pork	.71(13)	1.97(19)	1.64	1.17(0)	1.30(1)	.80	.97(13)	2.70(23)	2.26
Chicken	.39(9)	1.07(19)	.76	1.15(0)	1.15(0)	.46	.53(9)	1.47(19)	1.03
Producers prices (¢/lb.)									
Choice steers	.36(9)	.85(19)	.46	.86(0)	1.13(1)	.19	.50(9)	1.16(19)	.63
Utility cows	.19(9)	.45(19)	.12	.61(0)	.79(1)	.07	.26(9)	.62(19)	.16
Hogs	.30(13)	.84(19)	.70	.50(0)	.55(1)	.34	.41(13)	1.15(23)	.96
Chickens	.22(9)	.60(19)	.42	.64(0)	.64(0)	.26	.30(9)	.82(19)	.58
Feeder steers	.28(10)	.67(19)	.12	.97(0)	1.26(1)	.08	.39(10)	.92(19)	.15
Corn price (¢/bu.)	2.7(8)	8.5(24)	7.6	.3(6)	2.7(18)	2.3	3.7(8)	11.6(24)	10.5
Acreage (m. acres)	.136(9)	.426(25)	.392	.014(5)	.133(17)	.116	−1.401(1)[b]	−1.401(1)[b]	−.864

[a] The number in parentheses is the delay of the maximum response in quarters.
[b] Minimum.

to account for the 10% set-aside requirement on program participants (see Ryan and Abel). Thus, the new program reduces by 11¢ per bushel the effective support price with respect to 1977. By equations (22) and (23) of table 2, this change will produce a reduction in acreage planted for corn of 1.54 million acres, and a reduction of corn output of about 92 million bushels. The effect on prices will be modest. The market price of corn will increase by about 4.1¢ per bushel and the retail cost of meat consumption about 1.2% (table 6, column 2). On the other hand, the goal of the grain reserve program is to store 670 million bushels of corn equivalents, of which approximately 522 million bushels correspond to corn. By the end of 1979, this action can add up to 23.5¢ per bushel to the price of corn and 4.2% to the retail cost of meat (table 4, last column). The model also predicts decreases of the same magnitude if and when the grain is released to commercial channels.

Sensitivity of Multipliers to Alternative Model Specifications

Table 7 compares the long-run response of the retail cost of meat under three alternative specifications: the basic model (table 2), the basic model with the meat demand block reestimated after deleting those cross-prices with negative coefficients, and the basic model reestimated assuming first-order serial correlation for those equations not passing the DW or DH tests (see above). Table 7 shows that the response of the model varies little among the three specifications. Furthermore, a detailed comparison of specific multipliers (not reported here) confirmed the lack of sensitivity

Table 6. Permanent Changes in Exogenous Variables Resulting in a 3% Increase in the Retail Cost of Meat Consumption

	Change		
Exogenous Variable	Percent[a]	Units	Standard Deviation (1958–75)
Corn exports	12.4	55.7 m. bu.	95 m. bu.
Nonfed beef imports	−119.0	−508.5 m. lb.	124 m. lb.
Corn yield	−4.2	−3.64 bu./a.	13.74 bu./a.
Disposable income	4.7	$7.5 billion	$26.8 billion
Corn support price	−23.9	−27 ¢/bu.	16 ¢/bu.

Note: Estimation based on the cost of the 1975 meat basket.
[a] Percentage of change with respect to 1975 level.

Table 7. Long-Run Response of the Retail Cost of Meat Consumption to Permanent Changes in Exogenous Variables under Alternative Model Specifications

Exogenous Variable	Change in Exogenous Variables (Percent)[a]	Change in Exogenous Variables (Units)	Model Response[a]: Basic Model (table 1)	Model Response[a]: Constrained Estimation of Demand for Meat	Model Response[a]: Basic Model with First-Order Serial Correlation
			(%)	(%)	(%)
Corn exports	23	100 m. bu.	5.39	5.41	4.50
Nonfed beef imports	23	100 m. lb.	−0.59	−0.63	−0.85
Corn yield	1.2	1 bu. a.	−0.82	−0.82	−0.65
Disposable income	0.6	$1 billion	0.40	0.41	0.30
Corn support price	9	10¢/bu.	−1.12	−1.12	−0.91

Note: Percentage of change in the cost of the 1975 consumption basket.
[a] Percentage of 1975 level.

of the policy implications demonstrated in table 7.

Conclusions

Some of the findings derived from the analysis of the model are as follows: (*a*) While the slaughter of feeder calves and the placement of steers and hogs on feed are responsive to own price and the price of corn, the supply (slaughter) of beef, pork, and chicken are not responsive to the current (quarter) prices. These lags in the response of livestock supply to price are, of course, the basis for the observed cyclical behavior of the sector: (*b*) Acreage planted in corn is determined by the market and effective support price, with only small substitution between corn and soybeans and no discernible effect of payments for acreage diversion. (*c*) The forecasting performance of the model within and beyond sample is accurate relative to autoregressive forecasting. (*d*) The model is stable and can exhibit sustained cyclical behavior when disturbed by such factors as weather, exports, and government programs. (*e*) Analysis of the multipliers reveals that corn exports, yield, and consumer disposable income are more significant than nonfed beef imports and corn price supports as a source of fluctuation in retail and producer prices and acreage planted in corn. And (*f*) the multipliers for nonfed beef imports confirm the position taken recently by the Council on Wage and Price Stability concerning the impact of reduced quotas on retail prices. Unlike an earlier study by Freebairn and Rausser, however, we find that nonfed beef production varies inversely in the long-run with imports.

[*Received October 1977; revision accepted August 1978.*]

References

Arzac, E. R., and M. Wilkinson. "Stabilization Policies for the United States Feed Grain and Livestock Markets." *J. Econ. Dynamics and Control,* forthcoming.

Chen, D. T. "The Wharton Agricultural Model: Structure, Specification, and Some Simulation Results." *Amer. J. Agr. Econ.* 59(1977):107–16.

Chow, G. C. *Analysis & Control of Dynamic Economic Systems.* New York: John Wiley & Sons, 1975.

Christensen, L. W., and M. E. Manser. "Estimating U.S. Consumer Preferences for Meat with a Flexible Utility Function." *J. Econometrics* 5(1977):37–53. U.S. Bureau of Labor Statistics Work. Pap. 23, 1974.

Council on Wage and Price Stability. "Conditions of Competition in U.S. Markets Between Domestic and Foreign Live Cattle and Cattle Fit for Human Consumption." Comments submitted to the International Trade Commission, Washington, D.C., 12 July 1977.

Crom, R. J. "A Dynamic Price-Output Model of the Beef and Pork Sectors." USDA ERS Tech. Bull. No. 1426, 1970.

Durbin, J. "Testing for Serial Correlation in Least-Squares Regression When Some of the Regressors are Lagged Dependent Variables." *Econometrica* 38(1970):410–21.

Fair, R. C. "The Estimation of Simultaneous Equation Models with Lagged Endogenous Variables and First-Order Serially Correlated Errors." *Econometrica* 38(1970):507–16.

———. "A Comparison of Alternative Estimators of Macroeconometric Models." *Int. Econ. Rev.* 14 (1973):261–77.

Feldstein, M. S. "The Error of Forecast in Econometric Models When the Forecast-Period Exogenous Variables Are Stochastic." *Econometrica* 39(1971):55–60.

Fox, K. A. "A Submodel of the Agricultural Sector." *The Brookings Quarterly Econometric Model of the United States*, ed. J. S. Duesenberry, G. Fromm, L. R. Klein, and E. Kuh. Amsterdam: North-Holland Publishing Co., 1965.

Freebairn, J. W., and G. C. Rausser. "Effect of Changes in the Level of U.S. Beef Imports." *Amer. J. Agr. Econ.* 57(1975):676–88.

George, P. S., and G. A. King. *Consumer Demand for Food Commodities in the United States*. Giannini Foundation Monograph No. 26, University of California, Berkeley, 1971.

Hayenga, M. L., and D. Hacklander. "Monthly Supply-Demand Relationships for Feed Cattle and Hogs." *Amer. J. Agr. Econ.* 52(1970):535–44.

Heien, D. "Price Determination Processes for Agricultural Sector Models." *Amer. J. Agr. Econ.* 59(1977):126–32.

Houck, J. P., and M. E. Ryan. "Supply Analysis for Corn in the United States: The Impact of Changing Government Programs." *Amer. J. Agr. Econ.* 54(1972): 184–91.

Johnson, D. Gale. *Farm Policy Programs*. Washington, D.C.: The American Enterprise Institute for Policy Research, 1973.

Kulshreshtha, S. N., and A. G. Wilson. "An Open Econometric Model of the Canadian Beef Cattle Sector." *Amer. J. Agr. Econ.* 54(1972):84–91.

Langemeier, L., and R. G. Thompson. "Demand, Supply, Price Relationships for the Beef Sector, Post-World War II Period." *J. Farm Econ.* 49(1967):169–83.

Logan, S. H., and J. N. Boles. "Quarterly Fluctuations in Retail Prices of Meat." *J. Farm Econ.* 44(1962): 1050–60.

Meilke, Karl D. "An Aggregate U.S. Feed Grain Model." *Agr. Econ. Res.* 27(1975):9–18.

Nerlove, M. *The Dynamics of Supply*. Baltimore, Md.: Johns Hopkins University Press, 1958.

Ryan, M. E., and M. E. Abel. "Corn Acreage Response in the Set-Aside Program." *Agr. Econ. Res.* 24(1972):102–12.

Tapiero, C. S., and M. Wilkinson. "A Dynamic Production Function for a Reproducible Resource: Cattle Production and Supply Function." *Analyse et Controle de Systemes*. Rocquencourt, France: Institut de Recherche D'Information et D'Automatique, 1976.

Theil, H. *Theory and Measurement of Consumer Demand*, vol. 2. Amsterdam: North-Holland, 1976.

Tomek, W. G., and R. W. Gray. "Temporal Relationships among Prices on Commodity Futures Markets: Their Allocative and Stabilizing Roles." *Amer. J. Agr. Econ.* 52(1970):372–80.

Tryfos, P. "Canadian Supply Functions for Livestock and Meat." *Amer. J. Agr. Econ.* 56(1974):107–13.

U.S. Department of Agriculture. *Livestock-Feed Relationships-National and State*. ERS Statist. Bull. No. 530, 1974.

U.S. Department of Agriculture. Economic, Statistics and Cooperatives Service. *Feed Situation*, Feb. 1978.

Working, H. "The Theory of the Price of Storage." *Amer. Econ. Rev.* 39(1949):1254–62.

Notes

Internalizing Externalities of Phosphorus Discharges from Crop Production to Surface Water: Effluent Taxes versus Uniform Reductions

James J. Jacobs and George L. Casler

Some economists have argued that the "solution to pollution" is effluent taxes. Ideally, the effluent tax should be set at a level which equates marginal social costs of effluent reduction with marginal social benefits of such reduction. Because of the difficulty of measuring these costs and benefits, particularly the benefits, economists have suggested an alternate approach. This approach requires that a socially acceptable standard of environmental (water) quality be set. Effluent taxes could then be used to achieve this standard. It has been argued that effluent taxes would achieve this standard at lower social cost than would policies such as uniform treatment or uniform reduction in effluent discharge by each discharger (Kneese; Kneese and Bower; Baumol and Oates; Freeman, Haveman, Kneese). Horner has presented a concise review of the case for effluent taxes. Few economists have disagreed with this argument.

This article discusses an empirical comparison of the social costs and the cost to farmers of achieving given levels of reduction in phosphorus discharge from crop reduction for effluent taxes versus uniform reduction. A modified effluent tax, which would achieve the same water quality goals at a lower cost to farmers, is also analyzed.

Research conducted on phosphorus in recent years lends itself to an empirical test of the aforementioned issue (Casler and Jacobs). Companion research indicates that reduction in soluble phosphorus inputs would decrease algal production in lakes in temperate latitudes (Oglesby and Schaffner). Presumably there are social benefits of reduced phosphorus discharges to such lakes, at least over some range of reduction.

Case Study: The Fall Creek Watershed

This paper deals with a study which estimated the costs of reducing soluble phosphorus discharges to surface water from crop production in the Fall Creek watershed. The analysis is conducive to a comparison of an effluent tax policy with a uniform reduction policy. Fall Creek is a major tributary of Cayuga Lake, one of the largest of the Finger Lakes in central New York. The watershed covers 125 square miles and contains 130 dairy farms. The major crops grown are corn grain, corn silage, hay or hay crop silage, oats, and wheat.

Empirical Model

The cost of reducing phosphorus discharges due to surface runoff and soil erosion was estimated with a linear programming model of the production agricultural sector of the Fall Creek watershed. Production activities consisted of dairy cows, raised and purchased replacements, alternative crop rotations for each soil type, commercial fertilizer, purchased grain and protein supplement, and hired labor. Soil erosion losses for each rotation on each of nineteen combinations of soil type and slope were estimated using the universal soil loss equation (Wischmeier and Smith). Phosphorus losses were estimated from soil losses by using the phosphorus content of the topsoil and an enrichment ratio representing the increased content of phosphorus in the eroded material (Casler and Jacobs). Because all the soil eroded from fields does not reach the stream, an estimated delivery ratio of .1 for the watershed was incorporated into the model (U.S. Environmental Protection Agency). Soluble phosphorus, rather than total phosphorus, is believed to control algal production; thus, an estimate was made of the proportion of the total phosphorus discharged which was soluble.

A profit-maximizing solution of the LP model was computed with no restrictions on phosphorus discharges. This solution was constrained to resemble closely the farm production activities found in the watershed in a 1973 survey. To simulate uniform percentage reductions in phosphorus discharges from each farm, the LP model was divided into three subwatersheds. Each of these three subwatersheds was treated as a "farm." Phosphorus discharges in each subwatershed were reduced by 10% increments. To simulate the imposition of an effluent tax, a single restriction on phosphorus discharge from the entire watershed was introduced, also in increments of 10%. The shadow prices on each of these restrictions are the effluent taxes re-

---

James J. Jacobs is associate professor of agricultural economics at the University of Wyoming, and George L. Casler is professor of agricultural economics at Cornell University.

The authors acknowledge the helpful suggestions of Nelson Bills, A. Allan Schmid, and an anonymous *Journal* reviewer.

quired to achieve the given percentage reduction in phosphorus discharge.

Under each of the phosphorus reduction policies, the LP model computed the least-cost rearrangement of production activities to comply with the specified policy. For the uniform reduction policy, rearrangement could occur only within each subwatershed while under the tax policy, the rearrangement could occur within the entire watershed. The latter case is less costly because the reduction in phosphorus discharge can occur in the least-cost place within the entire watershed.

The reduction in phosphorus discharge was achieved by substituting cropping activities with lower phosphorus discharge (rotations with more hay and less corn) for those with higher phosphorus discharges. Because corn produces more feed energy per acre than hay crops, shifting rotations reduces the amount of energy produced in the watershed. However, it was profitable to hold cow numbers and milk production in the watershed at the levels in the initial solution. The cost of complying with either policy was the cost of purchasing additional feed from outside the watershed, less the reduction in production costs if hay rather than corn was grown. In the case of the effluent tax, farmers also would be required to pay the tax on the amount of phosphorus discharge remaining after any reduction in phosphorus discharge.

Empirical Results

The costs of reducing phosphorus discharge from crop production by 10% to 60% in the watershed are shown in table 1. Three sets of costs are shown: (*a*) social costs of achieving reduction in phosphorus discharge under each policy, (*b*) tax revenue collected, which is a cost to farmers and, (*c*) total cost to farmers of obtaining each phosphorus reduction with either policy.

The social cost is the cost to society of the feed production foregone within the watershed in order to reduce phosphorus discharge to Cayuga Lake. In terms of social cost, the effluent tax policy allows each level of phosphorus discharge reduction to be achieved more efficiently than does the uniform reduction policy, i.e., a smaller decrease in feed production in the watershed is required to achieve a given level of phosphorus discharge.

The results of the study are depicted graphically in figure 1. The graph shows that the social cost of

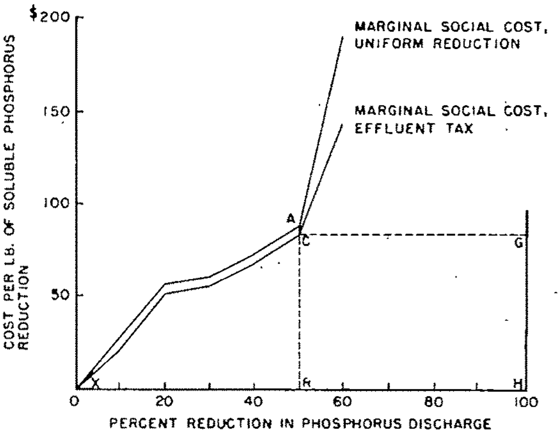


Figure 1. Social Costs of Decreasing Phosphorus Discharge from Crop Production in the Fall Creek Watershed by Policies of Effluent Tax or Uniform Reduction

achieving any level of phosphorus reduction is lower with the effluent tax than with uniform reduction in each watershed. For example, at 50% reduction, the social cost is *XAR* for the uniform reduction policy but *XCR* for the effluent tax policy.

While the social cost of reducing phosphorus discharge is less with the effluent tax policy, the total cost to farmers is much greater for the tax policy than for the uniform reduction policy (table 1). In addition to *XCR*, the farmers would pay a tax of *RC* per pound times the pounds of soluble phosphorus

Table 1. Costs of Reducing Soluble Phosphorus Discharge to Cayuga Lake from Crop Production in the Fall Creek Watershed with Uniform Reduction and Effluent Tax Policies

		Social Costs			
Reduction in Phosphorus Discharge (%)	Soluble Phosphorus Discharged[a] (lbs.)	Uniform Reduction Policy[b] ($)	Effluent Tax Policy ($)	Tax Revenue ($)	Total Cost to Farmers of Effluent Tax policy ($)
10	21,695.4	37,177	32,065	464,065	496,130
20	19,284.8	132,748	126,556	980,246	1,106,802
30	16,874.2	268,697	259,037	954,742	1,212,770
40	14,463.6	416,056	406,677	984,393	1,391,070
50	12,053.0	591,906	590,193	1,019,684	1,609,877
60	9,642.4	844,945	842,126	1,440,092	2,282,218

[a] The soluble phosphorus discharged before application of either policy was estimated to be 24,106 lbs.
[b] With the uniform reduction policy, social costs are also the total costs to farmers.

discharged, *RH*. Of course, the taxing body receives revenue (*RCGH*) equal to the tax paid by farmers.

Theoretical discussions have ignored the fact that total costs to dischargers may be higher with a tax than with either a uniform reduction or uniform treatment policy, and empirical studies have not stressed this point. An example used by Freeman, Haveman, and Kneese clearly illustrates that this may occur. In their example, while an effluent charge would have a social cost of $26 compared to $45 for uniform reduction and $56 for uniform treatment, the tax would be $72, making the total cost of the effluent charge policy to the dischargers $96 or roughly double the cost of either of the other policies. While the authors correctly point out that the tax revenue could be used for improving the quality of the stream and that it is a transfer payment, they fail to discuss the fact that the tax policy has implications concerning equity, administration, and political acceptance.

Another example is an article by Taylor and Frohberg in which a soil loss tax is compared with per acre restrictions on soil loss. While not intended as a test of effluent taxes versus uniform reduction or uniform treatment, their research does shed light on the effluent tax issue. The soil loss tax results in lower social costs for a given level of soil loss attained than does the alternative policy. This article also points out that the costs to landowners (farmers) is greater with the effluent tax than with the soil-loss restriction policy. The implications of the higher costs to farmers of the effluent tax policy were not discussed.

In our case the effluent tax that would be required to reduce phosphorus losses, when added to the reduction in income, makes the total cost to farmers of the tax policy substantially (2.7 to 13.3 times) higher than the cost of a uniform reduction policy. Furthermore, society may not be willing to accept such a policy because of perceived inequity of such a redistribution of income.

An Alternative Effluent Tax Policy

Effluent taxes have been shown in our work as well as that of other citations to have lower social costs than a policy of uniform reduction by all dischargers. The high costs (including the tax payment) to dischargers of the tax policy suggests that it may not be politically feasible or equitable to impose such a policy. While the effluent tax policy could be imposed on farmers without their consent, the high cost to farmers suggests that they would prefer the uniform reduction policy if forced to choose between the two. Their preference is illustrated rather dramatically in table 2. The reduction in net income (defined as labor and management income plus return to equity capital and estimated to be $12,000 per farm) is much larger with the effluent tax policy than with the uniform reduction policy.

Even if feasible, it may be questionable whether such a burden in terms of decreased income should be imposed on dischargers. This may be particularly important in the case of a substance such as phosphorus which may be a pollutant at high levels of discharge but is a nutrient (there would be no fish without it) at lower levels of discharge. There is no reason to tax dischargers on phosphorus when it is present in water only at nutrient levels.

An alternative effluent tax policy is proposed which would preserve the benefits of an effluent tax (lower social costs) and yet not be excessively burdensome to farmers. A straightforward approach is to choose the desired level of discharge and charge no tax on this amount.[1] Phosphorus discharges in excess of the desired amount would be taxed at a rate high enough to encourage farmers to reduce discharge rather than pay the tax. In effect, if farmers are rational, few taxes actually are collected, but the threat of a tax causes farmers as a group to reduce discharges to approximately the level desired in the watershed.

The LP model described above allows a straightforward application of this concept. Phosphorus discharge of the desired amount can be made free (not taxed) and a tax equivalent to the shadow price on each restriction, as discussed earlier, can be charged on discharge in excess of the desired amount. The shadow price, in effect, is the marginal value of the right to discharge phosphorus and in-

[1] This approach was suggested to the authors by A. Allan Schmid.

Table 2. Costs to Farmers of Reducing Soluble Phosphorus Discharge from Cropland in the Fall Creek Watershed to Cayuga Lake

Reduction in Phosphorus Discharge (%)	Soluble Phosphorus Discharge (lbs.)	Cost per Farm: Uniform Reduction ($)	Cost per Farm: Effluent Tax ($)	Percentage of Net Income: Uniform Reduction	Percentage of Net Income: Effluent Tax
10	21,695.4	286	3,816	2	32
20	19,284.8	1,021	8,513	9	71
30	16,874.2	2,067	9,337	17	78
40	14,463.6	3,200	10,701	27	89
50	12,053.0	4,553	12,384	38	103
60	9,642.4	6,500	17,556	54	146

creases as phosphorus discharge decreases. Therefore, for any tax chosen equivalent to or slightly higher than the shadow price or marginal value for the desired reduction, it is less expensive for farmers to reduce discharge than to pay the tax, so the desired reduction is achieved. No tax actually is collected, assuming that the farmers are rational. The cost to farmers for any level of reduction is the same as the social cost of the effluent tax policy as shown in column four of table 1. This also can be illustrated with figure 1. For example, at 50% reduction in phosphorus discharge, the total cost to farmers with the proposed effluent tax policy would be *XCR* rather than *XCR* plus *RCGH* under the usual effluent tax policy.

In the achievement of the desired reduction in discharge, say 40%, not all farmers will reduce discharge by the same percentage. Each will reduce as long as the marginal cost of reducing discharge is less than the effluent tax. This, of course, is the reason that an effluent tax policy is more efficient than a uniform reduction policy. It allows each discharger to choose between paying the tax and reducing discharge. Those who can reduce discharge least expensively will do so rather than some being forced to reduce discharge even at high cost. With this type of tax policy, the desired aggregate reduction can be achieved without imposing an undue tax burden on dischargers.

It should be recognized that the proposed effluent tax policy does not collect much tax revenue. If the desired reduction in phosphorus discharge has been chosen correctly; that is, if the free discharge is the precise point at which phosphorus ceases to be a pollutant and becomes a nutrient, there is no reason to collect a tax to compensate for the damage being done to water. Obviously, this precise point is unknown. If there is a desire to collect some tax as part of the effluent tax policy, this can be accommodated easily with the proposed scheme. The desired level of phosphorus discharge, rather than being made free, can be taxed at a rate to collect the desired amount of tax. As long as this is lower than the tax rate equivalent to the shadow price or marginal value of the desired reduction, farmers will have no incentive to reduce discharge below the level desired by the water quality manager. In our case, the tax per pound of phosphorus could be quite low and still gather a substantial amount of revenue. For example, at the 40% level of reduction, a tax of 75¢ per pound would raise $10,848 revenue and make the cost to farmers of the effluent tax policy about the same as the cost of the uniform reduction policy. As pointed out earlier, the difference between the economic costs of the effluent tax versus the uniform reduction policy is likely to be substantially greater in reality because there would be 130 farms in the watershed rather than the three pseudo-farms in our model. This difference would allow even more tax to be collected than in our example and have the cost to farmers be as low or lower for the effluent tax policy than for the uniform reduction policy.

[*Received January 1978; revision accepted November 1978.*]

References

Baumol, W. J. "On Taxation and the Control of Externalities." *Amer. Econ. Rev.* 62(1972):307–12.

Baumol, W. J., and W. E. Oates. "The Use of Standards and Prices for Protection of the Environment." *Swedish J. Econ.* 73(1971):42–54.

Casler, George L., and James J. Jacobs. "Economic Analysis of Reducing Phosphorus Losses from Agricultural Production." *Nitrogen and Phosphorus: Food Production, Waste and the Environment*, ed. Keith S. Porter. Ann Arbor, Mich.: Ann Arbor Science Publishers, 1975.

Freeman III, A. Myrick, Robert H. Haveman, and Allen V. Kneese. *The Economics of Environmental Policy.* New York: John Wiley & Sons, 1973.

Horner, Gerald L. "Internalizing Agricultural Nitrogen Pollution Externalities: A Case Study." *Amer. J. Agr. Econ.* 57(1975):33–39.

Johnson, Edwin L. "A Study in the Economics of Water Quality Management." *Water Resour. Res.* 3(1967):291–305.

Kneese, Allen V. *The Economics of Regional Water Quality Management.* Baltimore, Md.: Johns Hopkins University Press, 1964.

Kneese, Allen V., and Blair T. Bower. *Managing Water Quality: Economics, Technology, Institutions.* Baltimore, Md.: Johns Hopkins University Press, 1968.

Oglesby, R. T., and W. R. Schaffner. "The Response of Lakes to Phosphorus." *Nitrogen and Phosphorus: Food Production, Waste and the Environment*, ed. Keith S. Porter. Ann Arbor, Mich.: Ann Arbor Science Publishers, 1975.

Taylor, C. Robert, and Klaus K. Frohberg. "The Welfare Effects of Erosion Controls, Banning Pesticides, and Limiting Fertilizer Application in the Corn Belt." *Amer. J. Agr. Econ.* 59(1977):25–36.

U.S. Environmental Protection Agency. *Methods for Identifying and Evaluating the Nature and Extent of Non-Point Sources of Pollutants.* Washington, D.C., EPA-430/9-73-014, 1973.

Wischmeier, Walter H., and Dwight D. Smith. *Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains: Guide for Selection of Practices for Soil and Water Conservation.* USDA Agr. Res. Serv. in cooperation with Purdue University Agr. Exp. Sta., Agr. Handbook No. 282, 1965.

Measurement of Economic Benefits for Potential Public Goods

Ian Hardie and Ivar Strand

The computation of economic benefits is one of the more difficult tasks in the evaluation of publicly provided goods. Ideally, techniques for measuring these benefits would be derived directly from the theory of public expenditure. The theory, however, is a general equilibrium model of a frictionless world, one in which individuals simultaneously allocate their gross income among all existing and potential goods. Devices to accomplish this allocation include omniscient social planners (Samuelson) or social tatonnement processes (Malinvaud). These have no real counterparts, and their function is not easily built into techniques for measuring benefits from publicly provided goods.

We will explore some of the relationships between the public expenditure theory and current benefit estimation techniques in this paper. Benefit measurements are most often used on microeconomic problems by government agencies such as the Army Corps of Engineers or the National Park Service (U.S. Congress). Consequently, particular attention will be given to the assumptions needed to convert the theory's general equilibrium framework into a partial equilibrium framework suitable for the evaluation of benefits on an agency-by-agency basis. Within this partial equilibrium framework, we will examine the required conditions for consistency among the theory of public expenditure, benefit estimates derived from user-demand functions (for existing goods), and benefits derived from willingness-to-pay surveys.

We also suggest another technique for estimating benefits from government projects. The suggested expenditure simulator technique appears to have two advantages. It is a straightforward modification of the utility maximization problem inherent in the public expenditure theory, thus is easily related to that theory. It also offers an opportunity to eliminate some potentially troublesome assumptions of the existing techniques. The proposed method has not been completely implemented or tested: all that is available for presentation are some preliminary results. These results indicate, however, that the expenditure simulator has promise and merits further consideration.

The Individual in Public Expenditure Theory

The individual utility maximization problem inherent in the theory of public expenditure has been stated by Samuelson.[1] His expression, in slightly modified form, is

$$(1) \quad \underset{\mathbf{X},\mathbf{Q}}{\text{Maximize}}\, L = u(\mathbf{X},\mathbf{Q}) + \lambda(g - \mathbf{X}\mathbf{P}_X - \mathbf{Q}\mathbf{P}_Q),$$

where $\mathbf{X}$ is a (row) vector of all market goods and available collective consumption goods, $\mathbf{Q}$ is a (row) vector of potential collective consumption goods which can be provided by the government, $\mathbf{P}_X$ is a (column) vector of private good market prices and public good supply prices, $\mathbf{P}_Q$ is a (column) vector of "pseudo-tax prices" for the potential public goods, g is gross income after all transfer payments, and λ is the marginal utility of gross income.

This theoretical formulation includes all potential and available goods, whether public or private. Potential public goods are represented by $\mathbf{Q}$, while all existing public and private goods are in $\mathbf{X}$. $\mathbf{P}_Q$ represents the individuals' tax payments necessary for the provision of the new collective consumption goods. $\mathbf{P}_X$ contains both market prices and supply prices for the use of existing public goods. A notable feature of Samuelson's problem is that the government provides only collective consumption goods; all others are provided by the private sector.

Formulation (1) must be recast into a partial equilibrium framework if it is to be put into a form consistent with agency-by-agency benefit estimation. Partial equilibrium analysis implies the assumption that individual preferences are weakly separable for the goods in $\mathbf{X}$ and $\mathbf{Q}$ (Phlips). In addition, the division of potential public goods among the various agencies must follow the same separable preference groupings. Then problem (1) can be rewritten as

---

Ian Hardie is an associate professor and Ivar Strand is an assistant professor in the Department of Agricultural and Resource Economics, University of Maryland.

Scientific Article No. A2431, Contribution No. 5457, Maryland Agricultural Experiment Station.

The authors have benefited from comments by Virgil Norton, Robert Leonard, and two anonymous *Journal* reviewers. Lawrence C. Ervin assisted with the statistical analysis.

[1] We have expressed Samuelson's problem as a Lagrangian and have combined his income and transfer payment terms into gross income. Throughout the note, u is assumed to have the properties of a well-behaved utility function.

(2) $$\underset{X_j, Q_j}{\text{Maximize}}\, L_j = u(\mathbf{X}_j, \mathbf{Q}_j) + \mu(b_j - \mathbf{X}_j\mathbf{P}_{x_j}) + \theta_j(z_j - \mathbf{Q}_j\mathbf{P}_{Q_j}),$$

where $\mathbf{Q}_j$ is the group of potential public goods agency j can produce, $\mathbf{X}_j$ represents the available goods in preference grouping j; $\mathbf{P}_{x_j}$ and $\mathbf{P}_{Q_j}$ are the respective price subvectors, b_j is the disposable income allocated by the individual for the purchase of $\mathbf{X}_j$, μ is the marginal utility of disposable income, z_j is the part of the individuals' tax bill allocated to agency j, θ_j is the marginal utility of z_j. The function is maximized subject to the conditions that

(2′) $$\sum_j (z_j + b_j) = g, \text{ and}$$

(2″) $$\theta_1 = \theta_2 = \cdots = \theta_m = \mu = \lambda.$$

The difficulty of achieving a Pareto-efficient level of public goods production within a partial equilibrium framework becomes apparent in formulation (2). Not only do the individual preferences have to be weakly separable and the government agencies organized to account for the separability, but it is also necessary that the government's budget be allocated among the agencies so that production of public goods equates the individuals' marginal utility of income across the m preference groupings. This Pareto-efficient allocation of government expenditures would be required even if government programs are limited to corrections for market failures stemming from collective consumption and income redistribution accomplished by prior transfer payments.

Because the process of allocating public expenditures is outside the individual's control and is exogenous to the partial-equilibrium utility-maximization problem, we shall assume that a Pareto-efficient budget allocation has been made and concentrate on the intra-agency production problem. This assumption is consistent with agency-by-agency benefit estimation. It places the entire process of allocating budgets to government agencies beyond the scope of this note.

Benefit Measures from the Observed Demand for Existing Goods

One popular approach to the estimation of benefits for potential public goods measures these benefits by deriving changes in consumer's surplus. The changes result from expected supply price declines following the introduction of the new public goods. Estimation of the underlying demand curves required in this approach is accomplished through the use of supply price techniques such as the Clawson "travel cost" method (Clawson). A recent example of the approach is the "Mineral King" study by Cicchetti, Fisher, and Smith.

The individual utility maximization problem embodied in the approach is

(3) $$\underset{X_j}{\text{Maximize}}\, L^*_j = u(\mathbf{X}_j) + \mu(b_j - \mathbf{X}_j\mathbf{P}_{x_j}),$$

where $\mathbf{X}_j$, b_j, $\mathbf{P}_{x_j}$ and μ are as earlier defined. Formulation (3) is consistent with the multi-equation approach used in recent recreational demand studies (Gum and Martin, Cheshire and Stabler). As Vickerman has illustrated, multi-equation models remove the simultaneous equation biases of the older single equation models.

Comparison of problems (3) and (2) shows that demand functions based on supply prices can yield theoretically consistent benefit estimates only if $\mathbf{Q}_j$, the set of potential goods, is the same as $\mathbf{X}_j$, the set of available goods.[2] Otherwise, the marginal rates of substitution in formulation (3) will be different from those in problem (2), and the benefit estimates will suffer from specification error. Although the use of observed demands is appealing, we suspect it is difficult to find situations where the marginal rates of substitution among the available goods matches those of an agency's potential products.

Benefit Measures from Expressed Willingness-to-Pay

In cases where tradeoffs between potential public goods do not match existing choices, benefits have been estimated by aggregating individual's expressed willingness-to-pay (Bradford). The utility maximization problem implicit in this approach is

(4) $$\underset{X_j, Q_j}{\text{Maximize}}\, L^{**}_j = u(\mathbf{X}_j, \mathbf{Q}_j) + \mu(b_j - \mathbf{X}_j\mathbf{P}_{x_j} - \Sigma_i \Pi_{ij}) + \sum_{i=1}^{m} \gamma_{ij}(k_{ij} - q_{ij}),$$

where $\mathbf{X}_j$, $\mathbf{Q}_j$, μ, b_j and $\mathbf{P}_{x_j}$ are defined as before, and Π_{ij} is the individual's expressed willingness to pay for the ith potential public good, k_{ij} is the amount of public good i that the government agency is willing to provide, q_{ij} is the quantity of good i in $\mathbf{Q}_j$ that the individual would choose to consume, and γ_{ij} is the marginal utility obtained from an additional unit of good i. This utility maximization problem is formulated to fit a question of the form: How much would you be willing to pay to have the government provide k_i units of good i? Ideally, any number of goods could be handled in his formulation, although most willingness-to-pay survey techniques do not handle more than one or two potential goods (Ridker; Sinden; Randall, Ives, Eastman).

[2] Willig specifies some of the conditions necessary for consumer surplus to be an adequate measure of benefits. For expositional purposes, we accept consumer surplus as a valid measure of benefits.

A key element in formulation (4) is the inclusion of the Π_{ij} in the disposable income constraint. This is necessary to extract the individual's "true" willingness-to-pay, which is defined as the marginal rate of substitution between the potential good and a *numeraire* private good such as disposable income (Malinvaud). Most existing willingess-to-pay survey techniques rest on the assumption that individuals will give their true willingness to pay. This assumption may not always be met; both Samuelson and Malinvaud have stressed there is an incentive for a rational individual purposefully to misstate his or her willingness-to-pay if the amount is not actually paid. Such misstatements would, of course, directly affect benefit estimates based on the willingness-to-pay approach.

A Suggested Approach to Benefit Estimation

One possible approach to the estimation of benefits for government projects is to modify the theoretical partial-equilibrium formulation (2) by substituting an agency budget into the individual's choice problem. In the modified formulation, the individual's tax share would be replaced by the agency's budget (a_j) and the pseudo-prices would be scaled up to a magnitude equal to the entire cost (c_{ij}) of providing the public good. The utility maximization problem then becomes

$$(5)\quad \underset{\mathbf{X}_j,\,\mathbf{Q}_j}{\text{Maximize}}\ L^{***}{}_j = u(\mathbf{X}_j, \mathbf{Q}_j) + \mu(b_j - \mathbf{X}_j\mathbf{P}_{X_j}) + \theta_j(a_j - \mathbf{Q}_j\mathbf{C}_j),$$

where $\mathbf{X}_j$, $\mathbf{Q}_j$, μ, b_j, $\mathbf{P}_{Xj}$, and θ_j are defined as before, and a_j is a pre-set agency budget, $\mathbf{C}_j$ is a (column) vector of alternative costs of providing $\mathbf{Q}_j$. Problem (5) is stated so that each individual is allocating the agency's budget to produce maximum utility to the individual.

With a_j and $\mathbf{C}_j$ fixed, problem (5) becomes a constrained utility-maximization problem for the subset of public goods which agency j is authorized to produce. One possible way this constrained problem can be solved is to use a device similar to that employed in the Priority Evaluator Technique (Hoinville; Kirkley). Solutions from the interview device for different predetermined budgets and cost vectors will generate points on the individuals' demand curves for $\mathbf{Q}_j$. Representative pseudo-demand curves can then be obtained by weighting and pooling individual observations and employing econometric techniques such as restricted seemingly unrelated regressions estimation (Cicchetti, Fisher, Smith).

Once the representative demand functions are estimated for the predetermined set of potential goods, the allocation of the agency's funds to the goods can be found by maximizing

$$(6)\qquad B = \int_{\mathbf{Q}_j} D^{-1}(\mathbf{Q}_j)d\mathbf{Q}_j + \eta(\bar{\mathbf{a}}_j - \mathbf{Q}_j\bar{\mathbf{c}}_j),$$

where D^{-1} represents the inverse demand functions for $\mathbf{Q}_j$, $\bar{\mathbf{c}}_j$ is a (column) vector of the actual costs of providing $\mathbf{Q}_j$, expressed as the present value of the discounted time stream of project costs, $\bar{\mathbf{a}}_j$ is the agency's current capital budget allocated for the provision of $\mathbf{Q}_j$.[3] The public goods therefore would be selected to maximize a generalized agency surplus, given the representative demand curves and the agency's budget constraint.

This approach would be workable only if individuals have no money illusion. Given this assumption, the necessity of finding an exactly comparable set of available goods is eliminated by the specification of $\mathbf{Q}_j$ in the survey device. Moreover, using a suitably scaled agency budget in an individual utility maximization problem eliminates the incentive to misstate marginal rates of substitution between potential public goods. Thus, the suggested approach has some potential advantages over existing benefit measurement techniques.

Some Empirical Evidence

Existing surveys using the Priority Evaluator Technique (Hoinville, Pendse and Wyckoff) demonstrate that individuals can solve problems such as (5). However, these existing studies have been used to establish a set of equilibrium prices rather than to establish demand curves or measure economic benefits.

Although not principally designed to test the methodology suggested above, Kirkley's survey of Maryland park users provides some validation of the suggested approach. In the survey, park users were asked to allocate the capital budget of the Maryland State Park Service among five potential capital improvements: lakes, campgrounds, resort complexes, nature, and day-use facilities. Over five hundred interviews were conducted. Each included a change in total capital budget and in the prices for the capital improvements. Prices were expressed as percentages of the total budget for each park unit and respondents were required to spend the entire budget.

Survey design restricted the number of price changes to three per individual. Because prices were changed for only three of the five park types in the interviews, specification and estimation of a complete demand system were infeasible. Own-price demand functions are of the form:

$$(7)\qquad q_i = \alpha_{0_i} + \alpha_{1_i}p_i + \alpha_{2_i}a + \mathbf{A}\,\mathbf{S} + e_i,$$

where q_i represents the quantity of parks of the ith type, p_i represents a price based on the discounted unit cost of the ith park type, a is the sub-budget allocated to the three park types, $\mathbf{S}$ is a (column) vector of socioeconomic characteristics, $\mathbf{A}$ is a (row) vector of regression coefficients, and e_i is the

[3] For exposition, we have chosen to scale up the choice problem rather than to place the budget on a per capita basis.

error term. These functions were specified as an alternative and were estimated using ordinary least squares regression. Results from this estimation (table 1) provide some evidence of the plausibility of implementing the suggested approach.

Despite the probable specification error due to omitted cross-price variables, the signs on the own-price coefficients conform to demand theory and are statistically significant. Based on mean values, the own-price elasticities of nature parks, camping parks, and day-use facilities are .79, .78, and .28, respectively. The coefficients associated with sub-budgets are also significant in all equations, with day-use demand having the greatest increase per additional million dollars in the sub-budget (2.66). This might be expected, as these facilities cost on the average about one-half of the nature parks and about one-third of the camping parks.

Education increased the demand for nature parks, a finding consistent with that of Vaux, whose study showed higher income (and presumably better educated) groups and students preferred wilderness areas. If education is positively related to income and the students are generally college students, the two sets of findings are quite consistent.

Only two of the binary variables deserve attention. One would expect Maryland residents to prefer picnic and day-use areas because they are more readily accessible to the residents. Also, if camping requires basic skills more culturally available to males, then the result that males prefer camping parks more than females is to be expected.

Although the "pseudo" demand curves most likely have simultaneous equation bias and specification error, they can be used to illustrate the procedure to determine maximum agency surplus [equation (6)]. An average sub-budget of $6.4 million dollars was allocated to the three park types by the interview respondents. This budget, when combined with the estimated demand functions (table 1) and supply prices,[4] produced a sub-budget allocation in which 50% of the monies went to camping areas ($3.20 million), 34% to nature areas ($2.18 million), and 16% to day-use areas ($1.02 million).

Table 1. Regression Coefficients of "Pseudo" Demand Functions

	Park Type		
Independent Variables	Nature Parks	Camping Parks	Day-Use Facilities
Constant	.58	12.00	1.58
Continuous variables			
Price, nature parks	−33.35 (5.61)[b]		
Price, camping parks		−18.21 (5.54)	
Price, day-use parks			−63.67 (4.60)
Sub-budget	1.13 (9.52)	−.66 (9.20)	2.66 (11.64)
Education	1.12 (6.50)	−.28 (2.69)	
Binary variables			
Marital status	−5.65 (4.66)	2.05 (2.47)	
Resident		−1.53 (2.52)	4.64 (2.42)
Low income group[a]		−1.38 (2.04)	
Employment, sales	1.99 (1.85)		
Employment, blue collar		1.32 (2.02)	
Employment, service			8.80 (3.37)
Observations	565	565	565
$\bar{R}^2$	.27	.22	.23
F-statistic	43.44	21.30	42.72

[a] Low income group defined as having less than $6,000 disposable income.

[b] The t-statistics are in parentheses below figures.

Conclusion

Our preliminary test of the expenditure simulation approach suggests it may be a plausible way to solve the agency benefit-cost problem. Respondents are apparently able to reveal their preferences within the selected method and to do so in a manner which is consistent with classical demand theory.

The inability to explain a substantial portion of the variation in individual selections was the most negative aspect of the empirical test. Part of the reason for this may have been the survey design, which led people to believe that the first set of prices was more realistic than the second. Or it may be that respondents will not make choices simply on an economic rationale. Further exploration of the suggested approach should indicate which explanation is correct and should establish the value of the budget simulation approach to measuring economic benefits.

[*Received April 1978; revision accepted October 1978.*]

[4] Sample means were assumed for the socioeconomic characteristics in the demand equations. The specified costs (or supply prices) of the parks were: $.190 million for nature areas, $.320 million for camping areas, and $.098 for day-use areas.

References

Bradford, David F. "Benefit-Cost Analysis and Demand for Public Goods." *Kyklos* 23(1970):775–91.

Cheshire, P. C., and M. J. Stabler. "Joint Consumption Benefits in Recreation Site 'Surplus': An Empirical Estimate." *Regional Studies* 10(1976):343–51.

Cicchetti, Charles, Anthony C. Fisher, and V. Kerry Smith. "An Economic Evaluation of a Generalized Consumer Surplus Measure: The Mineral King Controversy." *Econometrica* 44(1976):1259–76.

Clawson, Marion. *Methods of Measuring the Demand for and Value of Outdoor Recreation*. Washington, D.C.: Resources for the Future, 1959.

Gum, Russell L., and William E. Martin. "Problems and Solutions in Estimating the Demand for and Value of Rural Outdoor Recreation." *Amer. J. Agr. Econ.* 57(1975):558–66.

Hoinville, G. "Evaluating Community Preferences." *Environment and Planning* 3(1971):33–50.

Kirkley, James E. "The Determination of Park-User Preferences for Facilities in Maryland State Parks." M.S. thesis, University of Maryland, 1975.

Malinvaud, E. "A Planning Approach to the Public Good Problem." *Swedish J. Econ.* 73(March 1971):96–112.

Pendse, Dilip, and J. B. Wyckoff. "Scope for Valuation of Environmental Goods." *Land Econ.* 50(1974):89–92.

Phlips, L. *Applied Consumption Analysis*. Amsterdam: North-Holland Publishing Co., 1974.

Randall, Alan, Barry Ives, and Clyde Eastman. "Bidding Games for Valuation of Aesthetic Environmental Improvements." *J. Environ. Econ. and Manage.* 1(1974):132–49.

Ridker, R. G. *Economic Costs of Air Pollution*. New York: Praeger Publishers, 1971.

Samuelson, Paul A. "Pure Theory of Public Expenditure and Taxation." *Public Economics*, ed. J. Margolis and H. Guitton. New York: St. Martin's Press, 1969.

Sinden, J. A. "A Utility Approach to the Valuation of Recreational and Aesthetic Experiences." *Amer. J. Agr. Econ.* 56(1974):61–72.

U.S. Congress. "Water and Related Land Resources, Establishment of Principles and Standards for Planning." *Federal Register*, vol. 38, no. 174, pt. III, 10 Sept. 1973.

Vaux, H. J., Jr. "The Distribution of Income among Wilderness Users." *J. Leisure Res.* 7(1975):29–37.

Vickerman, R. W. "The Evaluation of Benefits from Recreational Projects." *Urban Studies* 2(1974):277–88.

Willig, Robert D. "Consumer's Surplus without Apology." *Amer. Econ. Rev.* 66(1976):589–97.

Returns to Operator Education in Saskatchewan Agriculture

W. H. Furtan and Ray Bollman

Estimates of the rate of return to education in agricultural production indicate, for the most part, that education enhances the decision-making ability of farmers in an environment of rapid technological change. Welch has hypothesized that there are more opportunities for education to allocate resources across enterprises in an aggregate function than in a single-product production function. The estimates that indicate a high rate of return to education have related to both aggregate production functions (Huffman) and farm level production functions (Wu). Patrick and Kehrberg found both positive and negative returns to education in agricultural production functions in Brazil.

The purpose of this paper is threefold. First we wish to examine the inherent disequilibrium in Saskatchewan agriculture. This was accomplished by estimating the returns to scale that currently exist in the agricultural production function. Second, we wished to determine if education is an important input in the farm operation. Finally, we tested the hypothesis that the larger the number of enterprises in the firm, the higher the returns to education. This hypothesis was tested using farm firm production-function estimates on grain farms as compared to grain-livestock farms. It was assumed that grain-livestock farms have more enterprises than grain farms. On grain farms, a farmer can allocate resources across crops; however, these same decisions should be available to grain-livestock farmers. Following the hypothesis set out by Welch, we expect a higher return to education on grain-livestock (*GL*) farms than on grain (*G*) farms.

Theoretical Considerations

Farm firms operate in a dynamic environment of changing technology and varying prices. It is unlikely that they ever have perfect information regarding resource allocation to reach a position of competitive equilibrium. In the case that farm firms do operate in a state of disequilibrium, the ability of the decision maker to allocate resources in an efficient manner will result in increased profits to the firm (Schultz).

The decision-making ability of a farm operator can be expressed as a "worker effect"; that is, producing more with the available resources and an "allocative effect" which captures the effect of adopting new technology and the use of new inputs (Welch). Education can enhance both of these effects and thus increase the profitability of the farm firm. The importance of the allocative effect should increase, the greater the number of decisions to be made by the farm operators. Thus, one would hypothesize that the return to education in *GL* farms to be greater than on *G* farms.

Following Huffman and Welch, the gross revenue (or gross sales) production function for a *GL* farm can be written

$$Z = P_G \cdot q_1(X_1) + P_L \cdot q_2(X_2),$$

where P_G and P_L are the prices of grain and livestock, respectively, and the quantity of input X used in each production process is X_1 and X_2 ($X_2 = X - X_1$). If $X_1 = g(E)$, then the marginal product of education is

$$\partial Z/\partial E = (P_G \cdot \partial q_1/\partial X_1 - P_L \cdot \partial q_2/\partial X_2)dX_1/dE.$$

If $\partial Z/\partial E > 0$, then education enhances the decision-making process.

The marginal product of education includes both the allocative effect (dX_1/dE) and the worker effect ($P_G \cdot \partial q_1/\partial X_1 - P_L \cdot \partial q_2/\partial X_2$). Furthermore, the interaction between the two effects is hypothesized to be multiplicative rather than additive as hypothesized by Wu. The multiplicative interaction is acceptable because ability to reduce costs in any one enterprise and the ability to allocate resources across enterprises compliment one another. Huffman also found evidence of a multiplicative effect of education and extension which is not dissimilar to the hypothesis presented here in this paper.

Data and Estimation

The province of Saskatchewan is divided into twenty crop districts, each crop district having similar soil and weather-risk conditions. Within each crop district there are both *G* and *GL* farms, each of which is enumerated in the census. The census collects the years of schooling of the operators; thus it is possible to estimate cross-sectional production functions with education as an input. The data was taken from the 1971 census.

W. H. Furtan is an associate professor in the Department of Agricultural Economics, University of Saskatchewan, Canada, and Ray Bollman is an economist with Statistics Canada.

The farms were classified into two groups: those reporting revenue from the sale of grain and those reporting revenue from both grain and livestock sales. A further classification was used, in that grain farms reported no livestock capital, while grain-livestock farmers could report either revenues from livestock or livestock capital. There was no attempt made to classify *GL* farms or *G* farms into subgroups.

The model was the gross revenue production function,

$$(1) \qquad Z_j = A \prod_{i=1}^{6} X_{ij}^{B_j} \exp(E_j).$$

The variables were Z_j, which represents gross revenue of farm j with X_1 (land), X_2 (labor), X_3 (operator education), X_4 (livestock capital), X_5 (machinery capital), and X_6 (fertilizer and chemical use). The data in the production-function estimates were measured similar to that used by Khaldi. Land was the number of cultivated acres plus the unimproved land both rented and owned by the farmer. The education variable was entered in a weighted manner as suggested by Welch.[1] The total labor input was built up from operator labor, family labor, and hired labor. It was calculated as the number of weeks of available operator labor minus the weeks of off-farm operator labor plus 0.65 of the sum of family labor plus hired labor. Machinery was measured as cash machinery expenses plus 17% of machinery stock, while the livestock variable was livestock cash expenses plus 10% of livestock capital. Fertilizer and chemical expenses were summed and used directly in the production function.

An auxiliary equation was estimated to capture the allocative effect of education. This equation was

$$(2) \qquad X_j = TE_j^{\alpha} \exp(E),$$

where X_j was the amount of fertilizer and chemicals used on the jth farm and E was the weighted education level of the jth farmer. This formulation of the allocative effect was used for two reasons. First, fertilizer and chemicals only recently have been used extensively in Saskatchewan and the more progressive farmers have led in the adoption of this new technology (Furtan and Lee). Second, fertilizer and chemicals constitute an important cash cost to farmers on both grain and grain-livestock farms. In Saskatchewan, most of the grain fed to livestock is produced by the livestock farmer who feeds the grain. Thus, the fertilizer and chemicals usage may capture the allocative effect of the grain-livestock farmer. Thus it is possible using equation (2) to isolate the allocative effect of education on grain and grain-livestock farms.

Results

The output elasticities for representative crop districts 1B, 2B, 5B, and 7A are given in table 1. The output elasticities for the remaining crop districts are available from the authors. Range of output elasticities, degrees of freedom, and coefficients of determination for the remaining crop districts are given in table 2.

All the production functions indicated increasing returns to scale except for one crop district. The fact that increasing returns exist in most crop districts suggests that farmers have not fully captured all the efficiency benefits available to them based on present technology. Once increasing returns exist, there are forces within the firms that endogenize change or "they are engendered from within the economic system" (Young, p. 530). The lack of complete adjustment on the part of the farmers may be due to uncertainty as to future prices, yields, and government policy, plus the cost of education. This lack of full adjustment provides an avenue for the allocative effect of education to be an important economic variable.

The results in table 1 suggest that education is an important input on Saskatchewan farms. The positive effect of education is consistent with the previous result that firms are in a state of economic disequilibrium. The increasing returns to scale that exist in Saskatchewan agriculture would cause a demand for allocative ability on the part of the farm operators. By simply examining the output elasticities, one cannot conclude that education plays a more important role on either grain or grain-livestock farms. These elasticities are only capturing the "worker effect" of education on the farms and not the "allocative effect."

The allocative effect of education was estimated through auxiliary equation (2). The marginal allocative effect calculated at the mean is given in table 3. The results indicate that the allocative effect is positive (all were significantly different than zero at the 99% levels). The marginal product of the allocative effect for grain farms (*G*) in crop district 1B is 1.53. The marginal product of education with respect to the worker effect for 1B is 1002.36; thus, the composite marginal product is 1533.61 (1002.36 × 1.53). The composite marginal product is the relevant one to interpret as the two individual parts have little

[1] The education reported in the census gives the group level of educational attainment of the farm operator. The groupings were 0–5, 5–8, 9–11, 12–13, some university, and university degree. Because the education groupings did not include years of schooling, it was decided to weight them by the national income weights for similar education groupings. This allows the measurement of education to be a nonlinear transformation of the education groupings. Welch followed a similar procedure in his paper.

The weights used were:

0–5	5–8	9–11	12–13	some university	university degree
0.25	0.65	1	1.63	3.05	4.27

Because of the manner in which education is measured and weighted by national income, the marginal product of the allocative effect of education cannot be interpreted in the usual sense.

Table 1. Production Functions for Crop Districts 1B, 2B, 5B, and 7A

Crop district	1B	1B	2B	2B	5B	5B	7A	7A
Type of farm	*GL*	*G*	*GL*	*G*	*GL*	*G*	*GL*	*G*
Land	0.274	0.947	0.618	0.451	0.311	0.790	0.382	0.609
	(7.73)[a]	(6.30)	(13.33)	(6.15)	(10.30)	(11.55)	(7.32)	(11.17)
Labor	0.223	0.288	0.185	0.082	0.219	0.026	0.240	0.021
	(6.11)	(2.62)	(3.78)	(1.41)	(5.88)	(0.52)	(4.32)	(0.44)
Education	0.131	0.268	0.151	0.181	0.167	0.161	0.173	0.108
	(3.73)	(1.76)	(2.31)	(2.11)	(5.58)	(2.77)	(2.64)	(1.82)
Livestock	0.219		0.125		0.175		0.071	
	(12.38)		(5.68)		(12.41)		(3.69)	
Machinery	0.403	0.113	0.317	0.416	0.443	0.394	0.433	0.348
	(14.60)	(1.63)	(6.27)	(8.47)	(16.76)	(10.64)	(8.66)	(9.49)
Fertilizer and chemicals	0.067	0.112	0.057	0.151	0.125	0.065	0.001	0.053
	(4.60)	(1.55)	(2.38)	(4.95)	(9.84)	(2.39)	(2.86)	(2.71)
Constant	−0.059	−0.059	−0.28	−0.53	−0.41	−0.12	0.06	−0.27
	(−0.43)	(−0.9)	(−1.19)	(−1.52)	(−2.96)	(−1.01)	(0.26)	(−0.11)
Degrees of freedom	940	193	718	502	1996	791	494	441
$\bar{R}^2$	.62	.40	.59	.46	.54	.49	.55	.59
Σb[b]	1.31	1.71	1.45	1.28	1.44	1.41	1.36	1.11

[a] Student t values are in parentheses.
[b] Σb is the sum of the output elasticities significant at the 90% level for a one-tailed test.

meaning in themselves. If the national income weights remain constant, then a farmer, by increasing his education from one grouping to another, could pay $1533.61. One would not expect this to remain constant for all education groupings; however, to test this hypothesis would require further research.

There is, however, no indication that the allocative effect is consistently larger on grain or grain-livestock farms. There are two reasons why the allocative effect was so large on grain farms. First, the farmers can grow up to six different major grains and, depending upon the markets, the returns for each crop would be different. Thus farmers can allocate resources between crops. Second, because increasing returns exist on grain farms, there is a demand for the allocative effect of education. Consequently, we cannot reject Welch's hypothesis without further empirical investigation. When a firm is in the region of increasing returns to scale, and all factors of production have decreasing returns, there is no reason to suppose a firm will expand production by using more of any one particular input by itself. The firm may expand all inputs, assuming an unrestricted supply of factors, until an equilibrium is reached. If grain farmers pay the same price for resources as do grain-livestock farmers (except for land), the marginal value products (shown in table 4) of the inputs would give some hints as to which inputs farms would increase.

The marginal value products derived from the estimated production functions appear to be subject to question. The marginal value product of land per acre is unrealistically low; however, given that the

Table 2. Range of Output Elasticities, Degrees of Freedom, and R^2 For All Crop Districts

	Output Elasticities	
Type of Farm	Grain	Grain-Livestock
Land	0.976–0.335	0.636–0.181
Labor	0.288–0.0	0.391–0.0
Education	0.268–0.0	0.284–0.0
Livestock		0.245–0.079
Fertilizer and chemicals	0.276–0.032	0.125–0.0
Machinery	0.496–0.113	0.718–0.268
Degrees of freedom	791–250	354–1398
$\bar{R}^2$	0.63 –0.40	0.68 –0.55
Σ_b	1.72 –0.97	1.55 –0.98

Table 3. Allocative Effects of Education by Type of Farm

Crop District	dX/dE	Type of Farm
1B	1.53	*G*
1B	3.22	*GL*
2B	1.96	*G*
2B	1.77	*GL*
5B	2.66	*G*
5B	4.00	*GL*
7A	3.304	*G*
7A	1.19	*GL*

Table 4. Marginal Products for the Four Crop Districts

Crop District Types of Farm	1B *GL*	1B *G*	2B *GL*	2B *G*	5B *GL*	5B *G*	7A *GL*	7A *G*
Land	3.40	8.10	11.47	5.29	4.06	7.32	4.36	6.87
Labor	43.85	30.64	51.45	14.81	32.38	2.44	74.49	4.74
Education	3154.98	1533.59	2658.46	1680.50	4357.84	1441.66	1760.80	2133.97
Livestock	13.30		8.99		11.02		6.61	
Machinery	12.68	2.40	13.58	11.09	12.16	7.32	14.03	9.83
Fertilizer and chemicals	53.14	6.27	85.25	68.87	58.00	19.07	45.31	25.36

data was from the year in which Canada employed the LIFT[2] program, these numbers may be reasonable. The summer fallow acreage was extremely high and crop acreage much lower than usual, thus the low marginal value products for land. Labor which was measured in weeks is also low, suggesting that excess labor exists in Saskatchewan agriculture. On the other hand, machinery, livestock, and fertilizer plus chemicals, which were measured in dollars, had high marginal value products. The implication from this is that given the point in time, farmers could increase profits by employing resources so as to use their land more intensively. The marginal value product of education was positive, as shown in table 4. This is consistent with the result that farms on the average were in a state of economic disequilibrium, thus more education would enable the farmer to capture the benefits or opportunities that were present in the environment in which they operated.

Conclusions

The production-function estimates indicate that increasing returns to scale exist in all but one crop district. The increasing returns to scale suggest an endogenous change process within the firms given the present technology, thus the lack of full adjustment with respect to resource allocation.

The results supported the hypothesis that the returns to education were important for Saskatchewan farmers both for the worker effect and the allocative effect. The composite marginal product of education tended to be higher on grain-livestock farms than grain farms, which was in line with Welch's hypothesis. However, the allocative effect of education was present on both types of farms and, consequently, we were not able to reject Welch's hypothesis.

The input land continues to play an important role in Saskatchewan agriculture, as indicated by the magnitude of the output elasticities. This suggests that land is used in a relatively intensive manner, given the present known production technology. This way well be the case in Saskatchewan as many small acreage farms still exist while some farms are very large, and both operate in the same market with access to the same technology.

[*Received November 1977; revision accepted September 1978.*]

[2] The LIFT program was designed by the federal government to lower grain inventories by paying farmers to reduce their crop acreage.

References

Census of Agriculture: Saskatchewan 1971. Ottawa, Canada.

Furtan, W. H., and G. E. Lee. "Economic Development of the Saskatchewan Wheat Economy." *Can. J. Agr. Econ.* 25(1977):15–28.

Huffman, Wallace E. "Decision Making: The Role of Education." *Amer. J. Agr. Econ.* 56(1974):85–97.

Khaldi, Nabil. "Education and Allocative Efficiency in U.S. Agriculture." *Amer. J. Agr. Econ.* 57(1975): 650–57.

Patrick, G. F., and E. W. Kehrberg. "Costs and Returns of Education in Five Agricultural Areas of Eastern Brazil." *Amer. J. Agr. Econ.* 55(1973):145–54.

Schultz, T. W. "The Value of the Ability to Deal with Disequilibrium." *J. Econ. Lit.* 13(1975):827–47.

Welch, Finis. "Education in Production." *J. Polit. Econ.* 78(1970):35–59.

Wu, Craig C. "Education in Farm Production: The Case of Taiwan." *Amer. J. Agr. Econ.* 59(1977):699–709.

Young, Allen. "Increasing Returns and Economic Progress." *Econ. J.* 38(1928):527–42.

A Note on the Use of Sample Estimates in Optimization Models

Ross G. Drynan

Suppose one has m_1 independent observations x_{1j}, $j = 1, 2, \ldots, m_1$, on a random variable X_1, where $X_1 \sim (\mu_1, \sigma_1^2)$, and that one has to estimate the unknown μ_1.[1] What estimator should be used? An obvious estimator is $\bar{X}_1 = \sum_j X_{1j}/m_1$, for it is well known to be best linear and unbiased. An alternative estimator, which hopefully no one would consider seriously, is $X_1^0 = \max(X_{11}, X_{12}, \ldots, X_{1m_1})$, the sample maximum. The disadvantage of this particular estimator is that it is biased, for it is well known (Gumbel) that the mean of the distribution of the sample maximum increases with sample size. This bias would discourage most from knowingly using X_1^0 as an estimator of μ_1. Unknowingly, however, one might use it; and it is suggested in this paper that many situations arise in economics where one, in essence, does precisely that.

Consider the following scenario: a firm, about to implement a particular plan of action in a deterministic environment, is contemplating the performance measure, or the objective function value, μ_1, that will be achieved by implementing the plan. The firm possesses some less than perfect information about μ_1. Specifically, it has a set of m_1 independent observations x_{1j}, on a random variable X_1 distributed as indicated above, from which it calculates the sample mean, $\bar{x}_1$, as an estimate of μ_1. Furthermore, the firm is focusing on the particular plan of action rather than another plan because, of all plans considered, this particular plan is associated with a sample mean which is at least as great as the analogous sample means of the other plans.

In this paper it is suggested that the knowledge that the particular plan being implemented has been chosen through an optimization analysis based on sample data should lead the firm to question the appropriateness of $\bar{x}_1$ as an estimate of μ_1. In a classical inference framework, it is argued that $\bar{x}_1$ should be considered to be a biased estimate of μ_1, given the outlined scenario. The presence of bias should be recognized, particularly where the estimated performance measure of the plan is to be used in subsequent decision making. In practice, the actual bias in the estimate cannot be determined because it depends on the unknown performance measures of available plans. However, estimates of the bias can be made conditional on particular values of the performance measures. Procedures for making these estimates are outlined. A Monte Carlo analysis of a simple problem is included to illustrate the existence and the extent of bias.

The Basic Result

Suppose a decision maker wishes to choose one of n plans, p_i, $i = 1, 2, \ldots, n$, to maximize an objective function, where the objective function value for the ith plan is μ_i. Suppose that μ_i is unknown, but that the decision maker has access to a data set of n random samples of size m_i on n data-generating processes, where the individual observations (x_{ij}) within the ith sample are independent observations on the random variable X_i, where $X_i \sim (\mu_i, \sigma_i^2)$. With μ_i, $i = 1, 2, \ldots, n$, unknown, the decision maker can use $\bar{X}_i = \sum_j X_{ij}/m_i$, $i = 1, 2, \ldots, n$, as estimators of the unknown objective function values of the plans. Suppose the decision maker chooses that plan which has the greatest estimated objective function value. Let this plan be designated $P(x)$ to indicate that the chosen plan may vary from data set to data set. The chosen plan is then defined by

$$P(x) : \bar{x}_{P(x)} = \max_i \bar{x}_i;$$

and the random variable, $\bar{X}_{P(x)} = \max_i \bar{X}_i$, can be considered an estimator of $\mu_{P(x)}$.

Suppose, for the available data set, that the kth plan is the chosen plan. Then, for the available data set, $\bar{x}_{P(x)} = \bar{x}_k$, and $\mu_{P(x)} = \mu_k$. How good an estimate of $\mu_{P(x)}$ is $\bar{x}_{P(x)}$? To answer this, it is necessary to consider the estimator giving rise to the estimate, and the sample space on which the estimator is defined. There are three obvious cases to consider.

(*a*) The estimator of μ_k, $\bar{X}_k = \sum_j X_{kj}/m_k$, is defined for all possible data sets. Given the distributional assumptions above, $\bar{x}_k$ is an unbiased estimate of μ_k. Since $\bar{x}_{P(x)} = \bar{x}_k$, and $\mu_{P(x)} = \mu_k$, it is tempting to also say that $\bar{x}_{P(x)}$ is an unbiased estimate of $\mu_{P(x)}$. However, because the kth plan is not

---

Ross Drynan is a research associate in the Department of Economics and Business at North Carolina State University.

The author thanks the referees and editors for helpful suggestions in preparing the final version of this paper.

[1] Lower case letters are used to denote observations, variates, and estimates. Upper case letters denote random variables and estimators.

necessarily always the chosen plan, and because the properties of an estimate depend on the estimator from which it is derived, one must look at alternative estimators before anything can be said about $\bar{x}_{P(x)}$ as an estimate of $\mu_{P(x)}$.

(*b*) The estimator of $\mu_{P(x)}$, $\bar{X}_{P(x)} = \max_l \bar{X}_l$, is defined for all data sets. Not only does the actual estimate vary from data set to data set, but so does the chosen plan, and hence, so does $\mu_{P(x)}$. For a given data set, the error in the estimate will be $\bar{x}_{P(x)} - \mu_{P(x)}$. The estimator will be unbiased only if the expected error over all data sets is zero, that is, if $E[\bar{X}_{P(x)}] = E[\mu_{P(x)}]$. If this is so, then $\bar{x}_{P(x)}$ is an unbiased estimate of $\mu_{P(x)}$. The performance of $\bar{X}_{P(x)}$ as an estimator of $\mu_{P(x)}$ provides the firm with a measure of how well, on average, it will anticipate the performance of the plans it implements. For any particular plan the firm implements, a superior measure of how well, on average, it estimates the performance of the particular plan is obtained from the following estimator.

(*c*) The estimator of μ_k, $\bar{X}^*_k = (\bar{X}_k|\bar{X}_k \geq \bar{X}_i, i = 1, 2, \ldots, n)$, is defined for those data sets for which the kth plan is the chosen plan. The firm is only interested in the kth plan when it implements that plan. For the kth plan, the long-run evaluation of $\bar{X}^*_k$ as an estimator of μ_k will depend on the errors, $\bar{x}^*_k - \mu_k$, for the reduced sample space. If $E[\bar{X}_k|\bar{X}_k \geq \bar{X}_i, i = 1, 2, \ldots, n] = \mu_k$, then on average the firm estimates the performance of the kth plan when implemented without bias, and $\bar{x}^*_k$ is an unbiased estimate of μ_k.

The main result established below is that $\bar{X}_{P(x)}$ is a nonnegatively biased estimator of $\mu_{P(x)}$. The bias, $E[\bar{X}_{P(x)}] - E[\mu_{P(x)}]$, will be referred to as the overall bias because it is the bias in the estimated objective function value over all possible data sets. It also can be established that $(\bar{X}_k|\bar{X}_k \geq \bar{X}_i, i = 1, 2, \ldots, n)$ is a nonnegatively biased estimate of μ_k when $\bar{X}_i, i = 1, 2, \ldots, n$, have independent normal distributions. This bias will be referred to as an individual bias, and designated as bias (i), $i = 1, 2, \ldots, n$. For nonindependent or nonnormal distributions, an individual bias is not necessarily nonnegative.

To prove that the overall bias is nonnegative, consider the n sample means. Since $\max_i(\bar{X}_i) \geq \bar{X}_l$, $l = 1, 2, \ldots, n$, taking expectations over all possible data sets yields

$$E \max_i (\bar{X}_i) \geq E(\bar{X}_l),\ l = 1, 2, \ldots, n, \quad \text{or}$$

$$E(\bar{X}_{P(x)}) \geq \mu_l,\ l = 1, 2, \ldots, n.$$

Thus, the average estimated performance of implemented plans cannot be less than the actual performance of any of the available plans and must necessarily exceed the actual performance of all but the best plan. The overall bias is defined by $E[\bar{X}_{P(x)}] - E[\mu_{P(x)}]$, where the average of actual performances of implemented plans is given by

$$E[\mu_{P(x)}] = \sum_l p_l\mu_l,$$

where p_l is the probability that the lth plan is implemented. Because $\sum_l p_l\mu_l \leq \max_i \mu_i$, and $E[\bar{X}_{P(x)}] \geq \max_i \mu_i$, then

$$E[\bar{X}_{P(x)}] \geq E[\mu_{P(x)}],$$

and the overall bias is necessarily nonnegative. When at least one plan with $\mu_l < \max_i \mu_i$ has a nonzero probability of being chosen for implementation, $E[\mu_{P(x)}]$ is then smaller than $\max_l \mu_l$, and hence

$$E[\bar{X}_{P(x)}] > E[\mu_{P(x)}],$$

and the overall bias is positive. In reality, plans satisfying this condition will usually exist, and so will a positive bias in the estimated performance of chosen plans.

Discussion

The above result holds for all maximization problems in which one of a set of given plans has to be chosen based only on estimates of the objective function values of the plans. Because no use was made of the properties of the data-generating processes in proving the basic result, it holds for all forms of underlying distributions of the sample observations and applies whether or not the sample observations on the performance of different plans are independent. With dependence permitted, it applies to the common case where no direct observations on performance are available, but where observations are available on parameters common to the determination of the performance measures of the various plans. For example, in comparing alternative farm plans involving several different revenue-earning activities, sample observations on activity gross margins provide dependent observations on the performances of the alternative plans. Of particular note are linear programming formulations based on sample estimates of gross margins. This common formulation is compatible with the outlined scenario; the simplex algorithm, in essence, searching a finite set of bases and locating that with the largest estimated objective function. The presence of constraints does not affect the result. Constraints serve merely to define the set of feasible plans. They affect n, and hence, as indicated below, the size of the bias.

The assumption of a deterministic environment can be relaxed to an assumption of an environment with stochastic objective function values with expected values μ_i, $i = 1, 2, \ldots, n$, and realized objective function values $(\mu_i + \epsilon_i)$, $i = 1, 2, \ldots, n$, where $\epsilon_i \sim (0, \sigma_{\epsilon_i}^2)$. The previously defined estimators of μ_i can be applied to estimate μ_i with

identical conclusions. Thus, where the objective function values are stochastic, the long-run average estimated performance of implemented plans will be no less than the actual average performance of those plans.

The result for a discrete alternatives-maximization problem can be extended readily to a continuous action space problem, such as optimizing fertilizer application levels. Hence, in determining expected profit-maximizing fertilizer levels using an estimated production function, the estimated expected yield and profit associated with the optimal fertilizer levels will, on average, be no less, and probably greater, than the expected yield and profit. Finally, an analogous result holds for a minimization problem. The overall bias in this case is nonpositive.

Major limitation on the result is the requirement that the choice of a plan be based solely on the estimated objective function values. Thus, problems involving stochastic constraints, and in which some plans may sometimes be excluded from choice because they are infeasible, do not meet the requirements for the basic result. Simple examples can be constructed easily in which the bias is negative.

Nevertheless, the result remains quite general. Because normative economic problems are optimization problems of one form or another, and because uncertainty about performance is the norm, this bias pervades normative economics. Although the direction of the overall bias is dependent only on the mode of optimization (maximizing or minimizing), the actual overall bias depends on factors affecting how often a suboptimal plan is chosen and the value for the suboptimal plan relative to the optimal one. These factors include the differences between the largest μ_i and the other μ_j, $j = 1, 2, \ldots, n$ values; the number of alternative plans; the sample sizes, m_i, $i = 1, 2, \ldots, n$; and the properties of the joint distribution of X_i, $i = 1, 2, \ldots, n$, including the form, individual variances, and correlations.

Expressions for bias involving these factors are not readily obtained. However, a convenient expression has been obtained in the case where $(\bar{X}_i$, $i = 1, 2, \ldots, n$, can be assumed to be independently and normally distributed with mean μ_i and variance σ_i^2/m_i. The overall bias[2] is then

$$\sum_{i=1}^{n} \frac{\sigma_i}{\sqrt{m_i}} \int_{-\infty}^{\infty} \prod_{\substack{j=1\\ j\neq i}}^{n} F^*(zd_j) \sum_{\substack{j=1\\ j\neq i}}^{n} \frac{\sqrt{m_j}\, f^*(zd_j)}{\sigma_j\, F^*(zd_j)} f^*(zd_i)dz,$$

where $zd_j = (z - \mu_j)/(\sigma_j/\sqrt{m_j})$, and $f^*(\cdot)$ and $F^*(\cdot)$ are the standard normal density function and distribution function, respectively. Moreover, for this particular case, it can be shown that the individual bias in $(\bar{X}_k|\bar{X}_k \geq \bar{X}_i, i = 1, 2, \ldots, n)$ as an estimator of μ_k is nonnegative:

$$\text{bias}(k) = \frac{\sigma_k}{\sqrt{m_k}} \int_{-\infty}^{\infty} \prod_{\substack{j=1\\ j\neq k}}^{n} F^*(zd_j) \sum_{\substack{j=1\\ j\neq k}}^{n} \frac{\sqrt{m_j}\, f^*(zd_j)}{\sigma_j\, F^*(zd_j)} f^*(zd_k)dz \Big/ \left(1 - \int_{-\infty}^{\infty} f(z)F^*(zd_k)dz\right).$$

Thus, not only is the performance of implemented plans not underestimated on average, but the performance of a particular plan is not underestimated on average over the data sets for which that plan is implemented.

Even for this special case, which, because of the assumption of independence, is of restricted usefulness, the evaluation of overall bias and individual bias is not easy. First, bias depends on the unknown μ_j and σ_j values, $j = 1, 2, \ldots, n$. At best, one must be content with estimates of bias conditional on particular values of μ_j and σ_j^2, $j = 1, 2, \ldots, n$. Second, bias can be evaluated only numerically. Either a traditional numerical integration method or a Monte Carlo method would be needed. In either case, substantial computational effort is required, although less than needed when convenient expressions for bias are not available. In the latter situation, estimates of bias can be made using a Monte Carlo procedure in which the optimization problem is solved for a number of generated sample data sets to provide an estimate of the estimated performance measures of implemented plans.

Related Results

The bias question addressed in this paper has not been treated specifically, but several areas of literature deal with allied topics. Blumenthal and Cohen have considered a similar scenario as here and posed the problem of how to estimate the larger of two performance measures. By assuming nondegenerate normal distributions, they establish that $\bar{X}_{P(x)}$ is a positively biased estimator of the larger performance measure, that is, $E[\bar{X}_{P(x)}] - \max_i \mu_i > 0$. This latter bias is necessarily a lower limit on the overall bias defined herein, since $\max_i \mu_i \geq \sum_i p_i\mu_i$.

Closely related is the value of information literature, exemplified by Raiffa and Schlaifer. The value of information is defined as the expected difference between expected performance of plans chosen after receipt of information and the expected performance of the plan chosen without the information. Although a value-of-information analysis is necessarily cast in a Bayesian framework, in contrast to the classical inference framework used here, is computed analogously to the difference,

[2] The derivation of the bias expression has been omitted for brevity. Interested readers can obtain a copy from the author.

$E(\max_i \bar{X}_i) - \max_i \mu_i$, that is to $E[\bar{X}_{P(x)}] - \max_i \mu_i$. The value of information is thus computationally equivalent to Blumenthal and Cohen's bias, and would serve as a lower bound on the overall bias.

Finally, the familiar stochastic programming literature focuses on quantities very like those considered here. In contrast, the situation there is one of planning and estimating performance when the performance measures are stochastic with known probability distributions. In particular, the expected values of the performance measures are known, whereas the actual performance measures are stochastic. In the passive case of stochastic programming, or as Madanski called it, the "wait-and-see" case, specific plans are chosen for each possible stochastic event by choosing the best plan given the stochastic event. The expected plan performance prior to knowing the stochastic event is then a quantity computationally analogous to $E(\max_i \bar{X}_i)$. If a plan had to be chosen without knowledge of the stochastic event, the optimal choice would be that with maximum expected performance, $\max_i \mu_i$. The direct equivalence between the expected performance with and without knowledge of the stochastic event and the value of information has been noted by Bracken and Soland, among others.

Example

To illustrate the existence of bias and to show how it can be assessed, the Monte Carlo method was applied to a small example problem. A simple linear programming problem adapted from Heady and Candler was chosen for analysis. The problem is

$$\max_{\mathbf{w}} \bar{\mathbf{c}}'\mathbf{w}$$

$$\begin{aligned} \text{st.} \quad w_1 + w_2 + w_3 + w_4 &\leq 100 \\ w_2 + 0.5\, w_4 &\leq 100 \\ w_1 + 2w_3 \qquad &\leq 80 \\ w_i &\geq 0, i = 1, 2, \ldots, 4, \end{aligned}$$

where $\mathbf{w}' = (w_1, w_2, w_3, w_4)$ is a vector of activity levels, $\bar{\mathbf{c}}'$ is a 1×4 row vector of sample estimates of the vector of activity gross margins $\gamma' = [30, 10, 40, 12]$ with $\bar{c}_i = \sum_j c_{ij}/m_i$, $C_i \sim (\gamma_i, \sigma_i^2)$, $i = 1, 2, \ldots, 4$.

By considering two types of distributions for the C_i's (normal and lognormal), two sets of variances (36.0, 4.0, 64.0, 4.24; and 225.0, 25.0, 400.0, 30.0), and two sets of correlations between C_i and C_j (all 0.0, and all 0.6), eight problems were created. For each of these problems, samples of size $m_i = 4$, $i = 1, 2, \ldots, 4$, were generated randomly from the appropriate distributions. The sample means were calculated, and the resulting linear program solved. This process was repeated 100 times. In all, a total of 800 linear programs were solved. This provided estimates of the probability of particular plans being chosen, estimates of the individual bias in estimated performance for particular plans, and an estimate of the overall bias for each problem. The results of these computations are summarized in table 1.

The final line of table 1 reveals that the overall bias varies significantly from problem to problem. The presence of positive correlation between the observations on the activity gross margins reduces the overall bias, while increased variances are associated with increased overall bias. Because sample size will have an opposite effect to that of variance, increased sample size will reduce the overall bias. Moreover because the overall bias increases substantially when variance increases by a factor of 6.25, substantial reductions in overall bias should be obtained through moderate increases in sample size when the sample is small.

In contrast to variances and correlations, the form of distribution has very little effect on the overall bias. This was not unexpected for the example studied because, for the means and variances considered, the normal and lognormal distributions are not dissimilar. Cases involving greater relative differences could be expected to show greater disparities between the overall bias calculations.

The results suggest that the overall bias is relatively unimportant, at least for these problems. It is less than 12% of the long-run, average performance of implemented plans for all the problems considered, and less than 2.2% for those problems with the smaller variances. Plans are subject to varying amounts of individual bias depending on the distributional specifications. No clear pattern appears to exist. All plans are subject to significant individual bias in one or more problems, ranging as high as 18%. Some bias estimates are in fact negative, revealing either poor estimates or, more likely, that the individual bias in particular plans can be negative when the assumptions of normality and independence do not hold. Negative bias would occur when a plan tends to be chosen when its estimated performance is lower than its actual performance, other estimated performances (because of positive correlations and large variances) tending to be even lower.

Also reported in table 1 are the probabilities of particular plans being chosen, comparisons across plans reveal that the optimal plan ($w_1 = 80$, $w_4 = 20$; or $80_1 : 20_4$) always has the greatest probability of being chosen, but this may be as low as 0.41. Comparisons across problems show that the overall bias tends to increase as the probability of choosing a sub-optimal plan increases.

Conclusion

The small example presented here provides evidence of the existence of bias in optimization problems using sample data. Although the bias was relatively small for the example, in larger problems involving more plans, e.g., large linear programs, the extent of bias is likely to be higher, particularly

Table 1. Summary of Computations for Eight Hypothetical Linear Programming Problems

	Normal				Lognormal			
	Uncorrelated		Correlated		Uncorrelated		Correlated	
Plan and Actual Performance ($)	Low Variance	High Variance	Low Variance	High Variance	Low Variance	High Variance	Low Variance	High Variance
$(80_1:20_2)$	2,735.27	2,948.41[a]	—	2,904.25	2,740.70	2,918.10	—	2,903.08
	135.27	348.41[b]	—	304.25	140.70	318.10	—	303.08
2600	0.08	0.22[c]	0.00	0.15	0.07	0.23	0.00	0.12
$(80_1:20_4)$	2,671.38	2,877.39	2,650.65	2,751.22	2,666.73	2,805.18	2,645.98	2,704.43
	31.38	237.39	10.65	111.22	26.73	165.18	5.98	64.43
2640	0.80	0.41	0.96	0.64	0.80	0.43	0.97	0.67
$(40_3:60_4)$	2,467.29	2,642.69	2,366.54	2,515.12	2,506.93	2,669.99	2,367.40	2,537.20
	147.29	322.69	46.54	195.12	186.93	349.99	47.40	217.20
2320	0.12	0.29	0.04	0.14	0.13	0.28	0.03	0.16
$(60_2:40_3)$	—	2,511.83	—	2,103.48	—	2,599.71	—	2,188.04
	—	311.83	—	−96.53	—	399.71	—	−11.96
2200	0.00	0.08	0.00	0.07	0.00	0.06	0.00	0.05
	2,598.40	2,503.20[d]	2,627.20	2,558.40	2,595.60	2,514.80	2,630.40	2,562.00
	2,652.00	2,795.71[e]	2,639.29	2,695.78	2,651.13	2,780.97	2,637.62	2,675.69
	53.60	292.51[f]	12.09	137.38	55.53	266.17	7.22	113.69

[a] Long-run average estimate of plan's performance ($).
[b] Bias ($).
[c] Probability of being chosen.
[d] Long-run average actual performance of chosen plans ($).
[e] Long-run average estimated performance of chosen plans ($).
[f] Overall bias ($).

when the sample estimates are based on a limited amount of data. The firm should recognize not only that its chosen plan may be sub-optimal, but also that it in general cannot anticipate achieving the performance the available sample estimate suggests.

[Received December 1976; revision accepted December 1978.]

References

Blumenthal, S., and A. Cohen. "Estimation of the Larger of Two Normal Means." *J. Amer. Statist. Assoc.* 63(1968):861–76.

Bracken, J., and R. M. Soland. "Statistical Decision Analysis of Stochastic Linear Programming Problems." *Nav. Res. Log. Quart.* 13(1966):205–25.

Gumbel, E. J. *Statistics of Extremes*. New York: Columbia University Press, 1958.

Heady, E. O., and W. Candler. *Linear Programming Methods*. Ames: Iowa State University Press, 1958.

Madanski, A. "Inequalities for Stochastic Linear Programming Problems." *Manage. Sci.* 6(1960):197–204.

Raiffa, H., and R. Schlaifer. *Applied Statistical Decision Theory*. Cambridge: Massachusetts Institute of Technology Press, 1961.

The Value of Unrealized Farm Land Capital Gains

James S. Plaxico and Darrel D. Kletke

Capital gains in farmland occur over time but usually are considered to be realized when the asset is sold. Thus, the conventional manner of evaluating capital gains is to compute the present value of the after tax amount of the capital gains when the property is sold or at the end of the planning period (Lee and Rask). That is, the present value of anticipated capital gains assuming that the gains have value only when the asset is sold is defined by

$$(1) \qquad V_o = \frac{(P_n - P_o)(1 - T_c)}{\{[1 + D(1 - T)](1 + Z)\}^n},$$

where P_o is the purchase price of the property and P_n is the sale price or value of the property at the end of the planning period; T is the marginal income tax rate; T_c is the marginal income tax rate applicable to capital gains; D is the discount rate as determined by the opportunity cost of capital or the required internal rate of return (RIRR); and Z is the general rate of inflation as measured by an overall index such as the consumer price index (CPI) or the index of prices paid by farmers.

There appears to be no real consensus regarding the appropriate conceptual basis for establishing a discount rate. Alpin, Casler, and Francis (pp. 45–63) prefer the weighted average cost of capital (WACC) approach, but emphasize the WACC does not constitute a profit goal. Bierman and Smidt suggest the pure time value of money as the appropriate discount rate. They show that the rate must be adjusted for uncertainty to provide a required rate of return for each level of risk. They conclude that WACC is a useful concept but do not advocate its use in evaluating investments. The RIRR approach appears consistent with the economic concept of opportunity cost and is advocated by Adams (p. 539) and Hopkin, Barry, and Baker. The discount rate is important, but its definition is not central to the core argument of this paper. Inflation may be introduced by adjusting the discount rate or by adjusting the income flow (Alpin, Casler, Francis, chap. 11).

Land price increases have value over the planning period because such increases add to the wealth position (equity) of the owner (Boyne, Crowley, and Grove). This equity has current value because it reduces risk by reducing the degree to which equity is leveraged and/or by providing an equity base in support of additional borrowing capacity as a basis for business expansion. For example, Boyne suggests that proper consideration of capital gains and inflation, which he refers to as "nonconventional" income, is essential in order to evaluate rates or return on investment and to understand better consumption and production decisions. It follows then that the realized gain approach, i.e., V_o, underestimates the capital gains component of value (Bhatia).

An alternative way to value the stream of unrealized capital gains is to view it as equivalent to a tax-deferred income stream with the tax being paid at capital gains rates when the property is sold or at the end of the planning horizon. Referred to as Model II, this value is

$$(2) \qquad V_1 = \sum_{t=1}^{n} \left[\frac{(P_t - P_{t-1})(A)}{\{[1 + D(1 - T)](1 + Z)\}^t} \right] + \frac{(P_n - P_o)(1 - A) - (P_n - P_o), T_c}{\{[1 + D(1 - T)](1 + Z)\}^n},$$

where $A(0 < A < 1)$ is the proportion of the increase in equity in land in a given year, due to price increases, that is available as a financial reserve or as an equity base for expansion.

When increased equity arising from land price increases is employed to provide an equity base for additional borrowing, it is not necessary to make an interest charge against the increased equity. Rather, interest would be paid on the credit capital which becomes available as a consequence of the improved equity position. No tax would be paid on the annual equity flows as these are not realized gains. The same discount rate applies to equity flows as for ordinary income because increased equity and after-tax income are presumably perfect substitutes in providing an increased borrowing base. They are not substitutes in meeting cash flow requirements.

Few land owners purchase additional land each year. Thus, it is unlikely that land price-generated equity increases will be used each year as the equity base for land purchase. However, equity increases can be viewed as increased reserves which improve

---

James S. Plaxico is a professor, and Darrel D. Kletke is an associate professor in the Department of Agricultural Economics, Oklahoma State University.

Oklahoma Agricultural Experiment Station Journal Article No. 3476.

Two *Journal* reviewers and Clint Roush made several suggestions which have improved both the analysis and the presentation of this paper.

financial ratios (reduce the degree of financial leverage) and/or increase financial flexibility. Thus, annual land purchases, or other additional investments, are in no way a necessary condition for increased equity to have value on a flow basis. A relatively high A value would appear appropriate in cases where capital is very limited.

In Model II defined in (2), it is assumed that land price-induced equity increases have value only in the year the increase occurs. Another approach is to view the annual accumulative equity increases as available for investment during the year. This possibility, V_2, is defined as Model III and specified in (3),

$$(3) \quad V_2 = \sum_{t=1}^{n} \left[\frac{(P_t - P_o)(B)(D - r)(1 - T)}{\{[1 + D(1 - T)](1 + Z)\}^t} \right] + \frac{(P_n - P_o)(1 - T_c)}{\{[1 + D(1 - T)](1 + Z)\}^n},$$

where r is contract rate of interest, and B is proportion of accumulated equity arising from land price increases that is available as an equity base for additional credit. The value of B could range from zero to perhaps 4.0 (an implied equity requirement of 20%), depending on the nature of the loan.

The conceptual distinction between (2) and (3) is that in (2) annual equity increases are viewed as being available for a one-time equity extraction, while in (3) the accumulative increases are viewed as being invested continuously with interest paid each year. To make available the accumulative increase each year, it is necessary to borrow based on the increased equity and to pay interest. Thus, the flow value in (3) is the tax-adjusted difference between the annual rate of earning on capital (the discount rate) and the contract interest rate times the capital borrowed. Internal and/or external capital rationing determines the amount that will be borrowed based on the accumulated land equity. This is reflected in the B value used. Because the accrued gains are assumed to be an equity base which is not permanently extracted, the end values arising from (3) are the same as those in (1). In (3), larger flow values and larger total values are associated with higher B values and larger differences in the contract interest rate and the discount rate.

Comparison of Alternative Capital Gain Value Estimates

The value of capital gains using the three estimating procedures (models) are presented in table 1. In all cases a 5% rate of land price increase, a 9% interest rate, a 15% marginal tax rate, and a 12% discount rate are assumed. The impact of inflation is ignored and a ten-year planning horizon is used. The columns under "Base Information" apply to each of the three models. It is assumed that the beginning value of the land is \$100,000. Thus, in year one the value is \$105,000, and in year ten the land has an anticipated value of \$162,888. The next column shows the increment in value by years over the ten-year planning horizon. In the value of capital gains based on Model I (1), there is no flow value over the planning horizon; thus, all of the value is assumed to be realized at the end of the period. This amount adjusted to an after-tax present value is \$22,024.

Model II treats the available increment in value as an income flow in the year it occurs. Assuming an A value of 1.0, these increments total \$62,888. The capital gains tax constitutes a negative end value, leaving a net capital gain value of \$58,171, the same total as in estimate 1, the difference is in

Table 1. Annual Values of Capital Gains Over a Ten-Year Planning Horizon: Three Evaluative Models

	Base Information		Model I [equ. (1)] Capital Gains		Model II [equ. (2)] Capital Gains		Model III [equ. (3)] Capital Gains	
Year	Asset Value	Increment in Value	Value	Present Value	Value	Present Value	Value	Present Value
1	105,000	5,000	0.0	0.0	5,000	4,537	128	116
2	110,250	5,250	0.0	0.0	5,250	4,323	261	215
3	115,762	5,512	0.0	0.0	5,512	4,119	402	300
4	121,550	5,788	0.0	0.0	5,788	3,925	550	373
5	127,628	6,077	0.0	0.0	6,077	3,740	705	433
6	134,009	6,381	0.0	0.0	6,381	3,563	867	484
7	140,709	6,700	0.0	0.0	6,700	3,395	1,038	526
8	147,744	7,035	0.0	0.0	7,035	3,235	1,217	560
9	155,131	7,387	0.0	0.0	7,387	3,082	1,406	587
10	162,888	7,756	0.0	0.0	7,756	2,937	1,604	607
Flow value			—	—	62,888	36,855	8,177	4,201
End value			\$58,171	\$22,024	\$−4,717	\$−1,786	\$58,171	\$22,024
Total			\$58,171	\$22,024	\$58,171	\$35,069	\$66,348	\$26,225

Note: 5% year rate of land price increase, 0%/year rate of inflation, 9% interest, 12% discount rate, and assuming all of the value increase (equity) is available during the year.

the timing of the returns. Thus, the present value of gains is $35,069 for Model II.

Model III specified in (3) assumes that the value of the capital gain is the earning power of the additional credit available due to the increased equity. This flow value is added to the end of the period value. Using this approach, the flow value of the capital gains adjusted to a present value is $4,021 and the end value is $22,024, the same as Model I, for a total of $26,225. A value of 1.0 is assumed for both A in (2) and for B in (3). Using the same discount and interest rates, a B value of 3.0 would result in a present value of capital gains using (3) similar to that derived using an A value of 1.0 in (2).

The same interest and discount rates are used in each of the three estimates. This is appropriate for purposes of comparing the three models. However, if the different value concepts are associated with operators having different capital availability characteristics, operators with very limited capital may use a higher discount rate than those whose capital is less limited.

Impact of Selected Variables on Captial Gains Values

Data in table 2 indicate that the rate of land price increase, the length of the planning horizon, and the discount rate each have an impact on the capital gain value estimates and that the effect varies significantly between estimating models. The tax bracket also has a differential effect on the results of estimates from the different models, but the rate of land price change has the same relative effect on each of the estimates. In table 2 only the present values of the capital gains, which include both the flow value and the end value, are presented.

A higher discount rate results in a lower capital gains estimate for each of the models and for all combinations of tax rates, planning horizons, and rates of land price change examined. Model I results are reduced most by higher discount rates because all of the gain values are assumed to occur at the end of the planning horizon. Model III is the least affected because the higher discount rate increases the net rate of return on the additional borrowed capital. This increased flow in part offsets the lower value of future equity values associated with the higher discount rates.

Higher rates of land price increase obviously result in higher capital gains estimates regardless of the model used. However, there is no differential effect between the models. Thus, the percentage of change in the estimated capital gains values are the same for all models for a given change in the rate of land price change. The impact of the length of the planning horizon on the capital gains value estimate is dependent both on the model used and the discount rate. In the case of Model I, capital gain values tend to be higher for relatively short planning periods than for longer periods, particularly when the discount rate is relatively high. For Models II and III, particularly Model II, high capital gain values tend to be associated with longer planning horizons, because a part of the capital gains value is considered to have occurred as a flow over the planning period, while in Model I the total value is an end value.

Higher marginal income tax rates are associated with lower estimated capital gain values in the case of each of the three models and for all planning horizons, discount rates, and rate of land price change. However, of the three models, the tax rate affects Model I results most and Model II least, both on an absolute and on a percentage basis. A major reason is that in the case of Model II, equity increases assume value over the period and only the end of the period capital gains taxes are imposed. These results suggest that there is no basis for the often expressed view that the tax structure per se gives high income (i.e., high tax bracket) individuals a competitive advantage in the land market. For a finite planning horizon a higher tax bracket

Table 2. Estimates of the Value of Capital Gains: Three Evaluation Models

Source of Estimate	5% Rate of Land Increase				10% Rate of Land Increase			
	15% Tax Rate Discount Rate		40% Tax Rate Discount Rate		15% Tax Rate Discount Rate		40% Tax Rate Discount Rate	
	12	18	12	18	12	18	12	18
Ten-Year Planning Horizon								
Model I	22,024	14,009	19,048	12,116	55,814	35,503	48,271	30,705
Model II	35,068	28,364	32,093	26,471	85,480	67,942	77,938	63,144
Model III	26,225	23,443	22,013	18,776	65,526	57,140	55,126	45,979
Twenty-Year Planning Horizon								
Model I	21,921	8,869	18,958	7,671	75,940	30,726	65,676	26,574
Model II	57,805	40,353	54,843	39,155	172,233	112,566	161,971	108,414
Model III	32,412	27,753	26,364	21,001	104,563	80,449	85,882	61,672

Note: 9% interest rate, two inflation rates, two discount rates, two marginal income tax rates and two planning horizons.

results in a lower present value. This is consistent with other analyses (Adams). For an infinite planning horizon, present values are independent of the tax bracket.

Analyses not reported show that both inflation and the percentage of the equity considered to be available (*A* and *B* values) have important impacts on capital gains estimates from the different models. It is difficult to conceive of circumstances in which one would be interested in present value estimates in terms of current dollars. However, inflation has no differential effect on the present value estimate that is derived from the different models. Thus, the impact of inflation is in terms of absolute changes in all models as opposed to relative changes associated with the alternative estimating models.

The proportion of the accrued capital gains which is currently available (as measured by *A* and *B*) has a major impact on the capital gains estimates for Models II and III. Further, for similarly leveraged positions,[1] comparisons of results from these models are sensitive to differences in the discount rates and the contract interest rate.

Summary

It is well known that capital gains in farmland have been substantial over time and in recent years have been greater than net farm income. A better understanding of how capital gains in farmland affect consumption and investment behavior and asset prices could lead to a better understanding of the market for farmland. This, in turn, could lead to an improved basis for evaluating the impact of various policy proposals on the market for farmland. Thus, expanded research relating to both the macro and micro implications of capital gains in farmland would appear to be amply justified.

[*Received January 1978; revision accepted July 1978.*]

[1] Comparable leveraging might be defined as $B = \theta A$, where θ is the dollars that can be borrowed per dollar of available equity. If the lender requires a 25% equity in the combined value of the equity and the additional investment, the implied value of θ is 3.0. This follows from $\theta\left[\frac{1-W}{W}\right]$, where W is the percentage equity required.

References

Adams, Roy D. "The Effects of Income Tax Progressivity on Valuations of Income Streams by Individuals." *Amer. J. Agr. Econ.* 59(1977):538–42.

Alpin, Richard D., George L. Casler, and Cheryl P. Francis. *Capital Investment Analysis Using Discounted Cash Flows*, 2nd ed. Columbus, Ohio: Grid, 1977.

Bhatia, Kul B. "Capital Gains and the Aggregate Consumption Function." *Amer. Econ. Rev.* 62(1972): 866–79.

Bierman, Harold, Jr., and Seymour Smidt. *The Capital Budgeting Decision*. New York: Macmillan Co., 1975.

Boyne, David. *Changes in the Real Wealth Position of Farm Operators, 1940–1960*. Michigan State University Agr. Exp. Sta. Tech. Bull. 294, 1964.

Crowley, William D. "Actual Versus Apparent Rates of Return on Farmland Investment." *Agr. Finan. Rev.* 35(1974):52–57.

Grove, Ernest W. "Farm Capital Gains—A Supplement to Farm Income?" *Agr. Econ. Res.* 12(1960):37–42.

Hopkin, John A., Peter J. Barry, and C. B. Baker. *Financial Management in Agriculture*. Danville, Ill.: Interstate Publishers, 1973.

Lee, Warren F., and Norman Rask. "Inflation and Crop Profitability: How Much Can Farmers Pay for Land?" *Amer. J. Agr. Econ.* 58(1976):984–89.

Inflation and Farm Tractor Replacement in the U.S.: A Simulation Model

J. M. Bates, A. J. Rayner, and P. R. Custance

Two recent contributions to this *Journal* (Chisholm; Kay and Rister) have been concerned to extend the literature on the replacement problem to encompass the real world decision milieu of the farmer via taxation considerations. These extensions, while welcome and useful, seem to us to be incomplete in the inflationary world of the 1970s: specifically, they make no explicit allowance for the link between optimal replacement age and the nature of the allowances permitted by the taxation authorities in an economy with rising prices. We would suggest that inflation has not been so negligible in most developed economies that it can be disregarded in this aspect of farm decision making.

The principal purpose of this note, then, is an attempt to extend further the tax-adjusted replacement model to embrace relevant considerations of inflation. We shall extend the results of Kay and Rister, but whereas previous contributions have utilized discrete time models, we shall use a continuous time model. It may be noted that Perrin developed a continuous time depreciation model, but without consideration of taxation and inflation. His examples, however, utilized discrete, annual models only. It finds the optimal replacement age exactly, an advantage of some importance in its own right, but more important, one which enables the sensitivity of replacement to changes in other conditions to be assessed with greater precision.

Replacement Models with Inflation

Kay and Rister present an equation relating the present value cost of replacing a farm asset every n years over an infinite time horizon, PV_n, as

$$(1)\ PV_n = \frac{1}{1-(1+r)^{-n}}\{[C_o - C_n(1+r)^{-n}] + (1-T)\left[\sum_{k=1}^{n} R(1+r)^{-k}\right] - T(A_n\{1+r\}^{-1}) - T\left[\sum_{k=1}^{n} D_k(1+r)^{-k}\right] - I_n(1+r)^{-1}\},$$

where r is after-tax real discount rate; C_o, initial cost; C_n, resale price at end of year n; T, marginal income tax rate; R_k, repair cost in year k; A_n, additional first year depreciation allowance that can be taken with a replacement policy of n years; D_k, regular depreciation allowance in year k; and I_n, investment credit that can be taken with a replacement policy of n years. The full credit is claimed only if n is at least seven years. The model assumes that all expenses, tax, and replacement occur at year end.

Consider two modifications of the Kay and Rister model; the first, to allow for replacement at any time of the year and, the second, to introduce the effects of inflation. Alteration of the model to allow for replacement at any time of the year implies that n need not take integer values and that the age of the asset at replacement is measured in continuous time, starting at $n = 0$. To derive the optimal value for n we used a computer program which prints out values for all local minimum points; in addition, since certain conditions apply to such items as investment credit, costs for all whole number of years are also evaluated.

We have used the data provided by Kay and Rister, the only changes being those required to put the costs into continuous form. Thus the repair cost function, which denotes the annual rate of repair costs of a tractor of age k years becomes

$$(2)\qquad R_k = 464.211\ K^{0.5}.$$

To preserve comparability with the results of Kay and Rister, we have assumed that these repair charges are settled at the end of each full year, and that tax rebates, claimable against these charges, are received at the same time. The present value of all repair costs up to age n is given by

$$(2A)\qquad R^*_n = \int_{k=1}^{n} 464.211\ k^{0.5}(1+r)^{h},$$

where h is the integer part of k.

Inflation will affect all future money costs, but we do not believe it sensible to take a varying money value as our *numéraire*. We therefore propose to undertake all calculations in constant real terms (i.e., by maintaining purchasing power): if there is 5% inflation between one year and another, then \$105 in the second year is regarded as \$100 in the first year's money. This treatment means that, provided inflation affects different elements of cost in

J. M. Bates is senior lecturer in econometrics, and A. J. Rayner is reader in agricultural economics in the Department of Economics, University of Nottingham; P. R. Custance is lecturer at the National College of Agricultural Engineering, Silsoe, Bedford, England.

the same way, many of the terms in expression (1) remain unaltered. For example, this is true of capital costs and of repair costs, since we assume that they remain constant in real terms (i.e., their money costs increase in line with inflation).

Inflation does, however, affect the costs incurred by a farmer in three ways. First, taxes are based typically on historic costs. In particular, the allowances that can be claimed for "depreciation" of equipment are a significant element in tax allowances: if the inflation rate is significant, the model must properly allow for the loss in the real value of these allowances.

Inflation affects real costs in two other ways. Receipts and benefits from tax allowances are lagged, typically by about one year. In inflationary periods, these receipts are in depreciated money. In addition, when a farmer sells his equipment the difference between the resale price and the unexpired depreciation allowance is subject to tax. In inflationary times, resale prices for any given age of equipment are likely to be increasing and may well exceed the unexpired depreciation allowances which are based on historic costs.

Let the rate of inflation be e^f. If we assume that both the new and resale prices of the machine maintain their real value, then the present value costs over an infinite time horizon of replacing regularly after n years (which need not be integer) are given by

$$(3)\ PV_n = \frac{1}{1 - e^{-rn}} \Big\{ C_o - C_n e^{-rn}) + (1 - T)R^*_n - T(A_n e^{-(r+f)}) - T\Big(\int_{k=1}^{n} D_k e^{-(r+f)k}\Big) - I_n e^{-(r+f)} \Big\}.$$

Equation (3) differs from (1) in that the additional first year depreciation is now a tax deduction measured in depreciated money, assuming f is positive. Also the regular depreciation allowances, D_k, are based on historic costs. In addition, however, there typically will be some recapture or repayment of depreciation to be made when the machine is replaced; for while we assume, with Kay and Rister, that the replacement age is correctly anticipated, we do not assume that the farmer can anticipate inflation so as to correctly anticipate market value. More specifically, we assume the farmer correctly specifies the current resale price of machines when first purchasing the machine, but makes no allowance for possible inflation in resale prices. ("For convenience, the model assumes market value and replacement age are correctly anticipated so terms for recapture of depreciation . . . are not needed" Kay and Rister, p. 355.) But in the declining balance method, Kay and Rister also make allowance for recapture of depreciation, this method of depreciation not enabling the whole of the machine to be depreciated after n years. The recapture of depreciation can be written as

$$(4)\ T\Big\{(C_o - A_n C_o + A_n \hat{C}_n)\Big(\frac{n-2}{n}\Big)^n - C_n e^{fn}\Big\} e^{-(f+r)n}/(1 - e^{-rn}).$$

The term $\hat{C}_n$ signifies expected resale price of the machine.

The explanation of equation (4) is as follows: In year 1, additional first year depreciation is $A_n(C_o - \hat{C}_n)$. In year 1, regular depreciation of $\frac{2}{n}$ of remainder, i.e., $\frac{2}{n}[C_o + A_n(C_o - \hat{C}_n)]$, leaving $\frac{n-2}{n}[C_o - A_n(C_o - \hat{C}_n)]$ undepreciated. In year 2, regular depreciation of $\frac{2}{n}\left(\frac{n-2}{n}\right)[C_o - A_n(C_o - \hat{C}_n)]$, leaving $\left(\frac{n-2}{n}\right)^2 [C_o - A_n(C_o - \hat{C}_n)]$ undepreciated. In year n, amount undepreciated is $\left(\frac{n-2}{n}\right)^n [C_o - A_n(C_o - \hat{C}_n)]$. On resale, farmer obtains $C_n e^{fn}$ in money. Therefore recapture of depreciation on first tractor is

$$\left(\frac{n-2}{n}\right)^n (C_o - A_n C_o + A_n \hat{C}_n) - C_n e^{fn}.$$

With tax rate T, and payment in n years' time being in "depreciated money," recapture of depreciation leads to payment to farmer in real terms on the first tractor of

$$T\Big[(C_o - A_n C_o + A_n \hat{C}_n)\left(\frac{n-2}{n}\right)^n - C_n e^{fn}\Big] e^{-(f+r)n}.$$

Given replacement every n years, the sum of this expression is $\frac{1}{1 - e^{-rn}}$ times as large, namely equation (4).

Results

We have reproduced the results of the final column of table 3 of Kay and Rister's article. This column gives the costs and optimal replacement age using the declining balance method and incorporating investment credit and additional first year depreciation. Results are not reproduced for the zero tax rate, since a non-tax payer has no tax against which to set depreciation allowances. The results obtained are seen in table 1.

Before examining the effect of inflation, it should be noted that the cost figures on our calculations are slightly below those of Kay and Rister and result from the fact that our repair cost function as recorded in equation (2), though similar to that of

Table 1. Present Value Cost and Optimal Replacement Age

Tax Rate (%)	Discount Rate (%)	Cost and Replacement Age: As Recorded by KR	Reworked, Inflation = 0	Inflation 5% Per Annum	Inflation 10% Per Annum
25	1	155 550 (9)	155 277 (8.9)	162 159 (9.5)	167 167 (10.2)
25	3	57 316 (11)	57 209 (10.5)	59 360 (11.4)	60 845 (12.5)
25	5	37 541 (13)	37 512 (13.4)	38 683 (13.9)	39 490 (14.0)[a]
25	10	22 929 (14)	22 921 (14.0)[a]	23 494 (14.0)[a]	23 910 (14.0)[a]
50	1	101 831 (8)	101 254 (7.8)	114 817 (9.2)	124 080 (11.5)
50	3	39 123 (11)	38 883 (9.4)	43 088 (11.6)	45 711 (14.0)[a]
50	5	26 433 (13)	26 392 (11.5)	28 664 (14.0)[a]	30 189 (14.0)[a]
50	10	17 180 (14)	17 174 (14.0)[a]	18 258 (14.0)[a]	19 035 (14.0)[a]

[a] The tractor is replaced only at 14.0 years because it is assumed that its physical life is ended: given the functions used for maintenance costs and salvage, the machine would be retained beyond 14 years if still in good working order.

Kay and Rister, is slightly lower in many of the years.

The effects of inflation are to increase the magnitude of costs at any given replacement age. By choosing later replacement, the machine owner can reduce his present value of costs a little, but not sufficiently to bring them down to the "noninflationary" cost level. The higher the rate of inflation the greater the real value of costs, and the higher the optimal replacement age; but in each case, the absolute difference made decreases as the rate of inflation becomes higher. It may also be observed that the higher the tax rate, the greater is the effect of inflation, particularly on costs.

The effects of inflation when additional first year depreciation is not paid, nor investment credit given can be seen from the results recorded in table 2. Once again, inflation causes present value costs and the optimal replacement age to be increased. The results in tables 1 and 2 are based on the assumption that the replacement age is correctly anticipated. To do this, the farmer has to make a correct prediction concerning future rates of inflation.

In table 3 we assess the effects of assuming the length of life to be the same as the one which would have been optimal in a noninflationary period. The results given in table 1 were based on the assumption that the farmer correctly anticipated the length of life of his machine, but based his depreciation calculations on currently observed resale prices. We have also assessed the effect of correctly anticipating future resale prices, the results of which are given in table 4. Once again we observe that the higher the rate of inflation the greater the replacement age. These results, however, are really of academic interest only. First, the total costs are increased by specifying the inflation-affected resale price, so it would not pay the farmer to do this; second, the tax authorities do not normally favor such guesswork in calculating depreciation allowances. Given the assumptions of the method, however, the results are predictable. To claim larger depreciation allowance, it is necessary to keep machines longer, their loss of value in the later years of life exceeding the increase due to all prices increasing.

Finally, we may note that in an inflationary era, governments may move toward an increased depreciation proportion being claimable in the first year, the extreme form of this being a 100% depreciation allowance. The effects of different rates of inflation on replacement policy are noticeable, but total present value costs are not greatly affected, as is seen by a comparison of the results of table 5 with those of table 2. It may also be noted that, at low

Table 2. Present Value Cost and Replacement Age

Case	As Recorded by KR	Reworked	Inflation at 5% Per Annum	Inflation at 10% Per Annum
No investment credit; no additional FYD	60 934 (13)	60 894 (13.4)	63 006 (13.7)	64 377 (14.0)[a]
Investment credit only	57 509 (11)	57 419 (10.5)	59 842 (11.3)	61 519 (12.3)
Additional FYD only	60 686 (13)	60 637 (13.5)	62 456 (13.9)	63 656 (14.0)[a]

Note: Tax rate is 25%; discount rate is 3%.
[a] See table 1 footnote.

Table 3. Optimal Replacement Age Given Specific Assumed Lengths of Life of Equipment in Depreciation Calculations

Tax Rate (%)	Discount Rate (%)	Assumed Length of Life	Cost and Replacement Age		
			Inflation = 0	5%	10%
25	1	8.9	155 277 (8.9)	161 716 (10.4)	166 083 (11.4)
25	3	10.5	57 209 (10.5)	59 154 (13.4)	60 430 (14.0)[a]
25	5	13.4	37 512 (13.4)	38 588 (14.0)[a]	39 385 (14.0)[a]
25	10	14.0	22 921 (14.0)[a]	23 494 (14.0)[a]	23 910 (14.0)[a]
50	1	7.8	101 254 (7.8)	112 388 (12.1)	118 867 (14.0)[a]
50	3	9.4	38 883 (9.4)	41 675 (14.0)[a]	43 905 (14.0)[a]
50	5	11.5	26 392 (11.5)	28 266 (14.0)[a]	29 750 (14.0)[a]
50	10	14.0	17 174 (14.0)[a]	18 258 (14.0)[a]	19 035 (14.0)[a]

[a] See table 1 for notes.

Table 4. Depreciation Allowances Based on Correctly Anticipated Future Resale Prices

Tax Rate (%)	Discount Rate (%)	Cost and Replacement Age		
		Inflation = 0	5%	10%
25	1	155 277 (8.9)	162 359 (9.5)	167 921 (10.2)
25	3	57 209 (10.5)	59 443 (11.5)	61 089 (13.5)
25	5	37 512 (13.4)	38 722 (14.0)[a]	39 621 (14.0)[a]
25	10	22 921 (14.0)[a]	23 525 (14.0)[a]	24 008 (14.0)[a]
50	1	101 254 (7.8)	115 216 (9.2)	125 354 (14.0)[a]
50	3	38 883 (9.4)	43 246 (12.4)	46 072 (14.0)[a]
50	5	26 392 (11.5)	28 740 (14.0)[a]	30 452 (14.0)[a]
50	10	17 174 (14.0)[a]	18 319 (14.0)[a]	19 230 (14.0)[a]

[a] See notes to table 1.

Table 5. 100% Depreciation Allowance in First Year

Tax Rate	Disc Rate	Cost and Replacement Age		
		Inflation = 0	5%	10%
25	1	165 325 (11.4)	167 800 (12.4)	169 554 (13.3)
25	3	59 591 (13.9)	60 232 (14.0)[a]	60 771 (14.0)[a]

[a] See notes to table 1.

rates of inflation, 100% initial allowances are not as beneficial as the 7% investment credits.

The purpose of this note has been to describe the way in which inflation may be incoporated in replacement decisions. The rate of inflation can have sufficient impact on the optimal age of replacement for its inclusion in a replacement model to be justified.

[*Received July 1977; revision accepted October 1978.*]

References

Chisholm, A. "Effects of Tax Depreciation Policy and Investment Incentives on Optimal Equipment Replacement Decisions. *Amer. J. Agr. Econ.* 56(1974): 776–83.

Kay, Ronald D., and Edward Rister. "Effects of Tax Depreciation Policy and Investment Incentives on Optional Equipment Replacement Decisions: Comment." *Amer. J. Agr. Econ.* 58(1976):355–58.

Perrin, R. K. "Asset Replacement Principles." *Amer. J. Agr. Econ.* 54(1972):60–67.

Relationships among North American Fats and Oils Prices

G. R. Griffith and Karl D. Meilke

Over the last decade the North American fats and oils sector has been the subject of considerable economic research (Boutwell et al.; Duncker; Houck and Mann; Houck, Ryan, Subotnik; Labys 1975, 1977; Nyberg; Vandenborre). While much of this research effort has been directed toward developing econometric models of the sector, the price and substitution relationships among the various fats and oils also have been emphasized.

There are at least four reasons why an understanding of the price relationships among the various fats and oils is of interest. First, the activities of some oilseed producers in restricting exports has caused concern over the security of oilseed supplies and access to markets. If these restrictive policies are repeated, both importers and exporters are vitally interested in the impacts on price levels and alterations in demand that will be forthcoming.

Second, a number of fats and oils have been included in the UNCTAD proposals for international multicommodity agreements, and some (the lauric oils) have been proposed as candidates for an international buffer stock scheme (UNCTAD). Detailed analysis of the feasibility of buffer stock proposals cannot be made until it is established which oil or group of oils (if any) would be part of the stock, and such a decision depends to a large extent on the substitution possibilities between the various fats and oils.

Third, in constructing econometric models of the total fats and oils complex, a difficult decision must be made about how to aggregate the many different commodities. Obviously the best solution is to aggregate only those commodities whose price movements are very similar.

Fourth, although all of the fats and oils are subject to similar demand pressures (increasing population and income), the reactions to these variables are probably quite different. For this reason, certain commodity prices may, in the short run, lead or lag price changes of other commodities in the sector, or exhibit different degrees of response to price changes so that their stability over time will be different.

G. R. Griffith is an economist with the New South Wales Department of Agriculture, Australia, currently on study leave at the University of Guelph, Canada. Karl Meilke is an associate professor of agricultural economics, University of Guelph.

The authors acknowledge helpful comments by T. K. Warley and the *Journal* reviewers. This project was funded by the Ontario Ministry of Agriculture and Food and Agriculture Canada.

Relationships between Fats and Oils: Technical Considerations

Animal and vegetable fats and oils are glycerides of fatty acids. The physical properties of the different types and their potential for substitution vary according to the type and proportions of the fatty acids they contain. Table 1 indicates the four major classifications of fats and oils, various subclasses within the major classifications, and individual oils within each subclass that are analyzed in this study. In the tables and the text, "edible" refers to the four soft vegetable oils used for predominantly edible purposes (cottonseed oil, peanut oil, soybean oil, and rapeseed oil), and "palm" refers to the two oils derived from palm trees (palm oil and coconut oil).

In food uses such as salad oils, spreads, frying, and cooking, all the edible fluid vegetable oils are theoretically interchangeable. These possibilities for substitution are limited to some extent by customer preferences for particular oils, preferences for specific qualities such as smell or taste, dietary considerations, and the suitability of some of the nonhydrogenated semi-drying oils (especially maize oil, safflower oil, and sunflowerseed oil) for the industrial production of dressings, mayonnaise, or margarine (FAO). Further, for frying and cooking uses, the oils must be stable and resist breakdown when heated, so the saturated fats and oils have traditionally been used for these purposes. Hydrogenation, blending, and other improvements in processing technology, however, have reduced the impact of many of these barriers to interchangeability.

In industrial products interchangeability varies according to the type of use. Certain users have specific technical requirements in their demand for fats and oils because the different types confer different properties on the finished product. Soap manufacturers can use a wide variety of fatty acids, although a certain quantity of foaming fatty acid, such as lauric acid, is required. Fatty acid manufacturers base their choice of oils solely on the quantities of the one or more acids they can obtain by fractionation.

Thus technical interchangeability varies according to use. When fats and oils are used for food consumption, substitutability is high although tastes and habits often limit choice. In industrial use substitutability is high when fats and oils are used in

Table 1. Classes of Different Fats and Oils, Volume of Trade, and Definitions of Commodities Studied

Class	Subclass	Example	Use	1975 Exports Thousand Tonnes	1975 Exports % of Total
Soft vegetable oils	drying	linseed (*LIN*)[a]	industrial	266	1.9
	semi-drying	soybean (*SOY*)	edible and industrial	3,539	25.9
		cottonseed (*COT*)		407	3.0
		rapeseed (*RAPE*)		611	4.5
	nondrying	peanut (*PN*)	edible	735	5.4
Solid palm oils	palm	palm (*PALM*)	edible	1,772	13.0
	lauric	coconut (*COC*)	edible and industrial	1,528	11.2
Animal fats		lard (*LARD*)	edible and industrial	516	3.8
Marine oils	fish	menhaden (*FISH*)	edible and industrial	558	4.1
		others not listed		3,737	27.2
Total				13,669	100.0

Sources: FAO (1971), USDA (1977a, 1977b).

[a] Variable definitions: *LIN*, raw, tank carlots, New York; *SOY*, crude, tank cars, FOB, Midwest mills; *COT*, crude, tanks, FOB, Valley Points; *RAPE*, refined, denatured, tank cars, New York; *PN*, crude, tank cars, FOB, Southwest mills; *PALM*, tank wagons, FOB, New York; *COC*, crude, tanks, FOB, New York; *LARD*, loose, tanks, Chicago; and *FISH*, refined, light pressed, drums, New York.

mixed form, but technical requirements may restrict choice in particular usages.

Relationships between Fats and Oils: Economic Considerations

The ultimate interchangeability between fats and oils is determined at the processing level where the manufacturer is subject to the constraint of input prices relative to output prices. The effect of this economic constraint will be stronger or weaker according to the type of demand relationships in the markets for the different fats and oils. In markets with specific demands, end users attach high importance to certain natural characteristics which cannot be artificially reproduced and for which they are prepared to pay higher prices; for example, specific preferences for olive oil in certain food uses. In this type of market there is little or no substitution among inputs and the price of each is determined independently of others.

In markets with interchangeable demands, end users are largely indifferent to manufacturers choice of inputs and they refuse to pay prices for the processed product inconsistent with least-cost formulation; for example, fats and oils used in oleic acid manufacture, soaps, and margarine. This high degree of interchangeability in demand implies the prices of fats and oils in these markets are strongly interdependent.

The fact that most fats and oils have many possible end uses has sometimes led to the erroneous assumption that they are freely substitutable in all uses. However, the substitution that does occur between the various fats and oils depends on both relative prices and their physical and chemical properties.

Given this general background, the aim of this paper is to provide quantitative information on the price behavior of representative U.S. fats and oils, and on the substitution patterns between them. In so doing, three hypotheses about the relationships among fats and oils prices will be examined: (*a*) the prices of oils with similar characteristics and similar end uses will be strongly interdependent; (*b*) price interdependencies are becoming more marked over time in markets with strong interchangeable demands; and (*c*) even for products with similar demand characteristics, short-run price behavior may be substantially different in terms of the extent and the timing of responses to changes in other prices.

Methods and Data

There have been several previous attempts to measure the relationships between North American fats and oils prices (Labys 1977; Nyberg; Vandenborre), but most have confined their attention to graphical analysis or simple correlation analysis, and all have used annual data. There would appear to be a major deficiency with these simple analyses, based on annual data, in that they do not take account of the extent or direction of within-year changes in the relationships between prices. Re-

sults may indicate a strong, positive relationship in the long term, but they can say nothing about the cyclical, seasonal, or irregular components of this relationship. Implications drawn from such analyses, for example with respect to buffer stock schemes, would give no idea of the possible distortions caused by within-year effects or the impact of such distortions on the economic variables in the market.

To overcome this deficiency, this study employs the statistically more powerful techniques of spectral and cross-spectral analysis. The theory of these techniques is well documented (Fishman; Granger and Hatanaka), as are a number of applications to agricultural markets (Barksdale, Hilliard, Ahlund; Parikh). In applying the techniques, all series were detrended by employing a first difference filter, and a maximum lag of twenty-four was selected so that the annual frequency and its harmonics would be estimated by integer values. An examination of the transformed data revealed that the trend removal achieved approximate stationarity.

The data used consists of 216 monthly observations on U.S. wholesale prices of fourteen fats and oils over the period January 1959 to December 1976, where all prices are measured in cents/pound. Of these fourteen series, the results for nine are reported below. These were selected on the basis of their importance in trade and so that every classification of fats and oils would be represented. The relative importance of the nine products (cottonseed oil, peanut oil, rapeseed oil, soybean oil, linseed oil, coconut oil, palm oil, lard, and fish oil) in export trade is indicated in table 1 as are definitions of the prices used. All series are undeflated because of our interest in the relationships between prices rather than their absolute value and because of the difficulty of choosing and applying an appropriate monthly deflator.

Results

Figure 1 contains the estimated power spectra of the four edible vegetable oil prices (soybean oil, cottonseed oil, peanut oil, and rapeseed oil), while figure 2 contains the estimated power spectra of linseed oil, coconut oil, palm oil, lard, and fish oil prices.

As shown in figure 1, all four spectra exhibit relatively low power in the lowest frequency band (the long-run cycle). This confirms that the trend removal method was effective. There is strong evidence of a four-year cycle in rapeseed oil prices and weaker evidence in the other three prices. There is some weak indication of an annual cycle in soybean oil prices, and both soybean and cottonseed oil prices exhibit very strong cyclical activity near the six-, three-, and two-month frequency bands. In addition, rapeseed oil prices contain strong seven- and three-month cycles, and peanut oil prices also exhibit evidence of a six-month cycle.

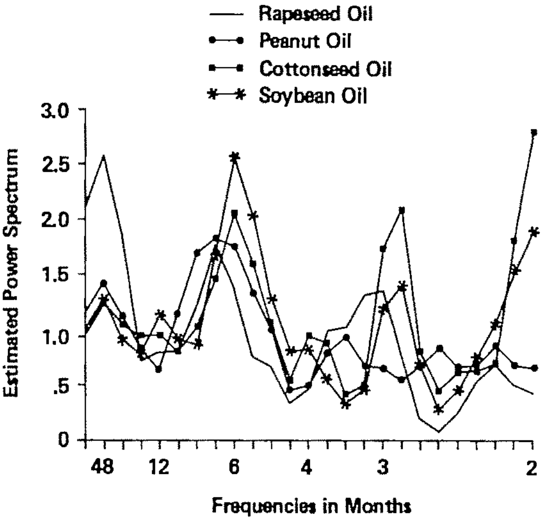


Figure 1. Estimated spectra of the prices of rapeseed, peanut, cottonseed, and soybean oils

The five spectra in figure 2 also show low power in the lowest frequency band. The coconut oil price spectrum contains a very powerful 24- to 48-month cycle and there is weak evidence of another cycle near the four-month frequency band. A four-month cycle is also evident in palm oil prices. There is a relatively strong annual cycle in lard prices, and this is reinforced by the presence of peaks at the harmonic frequencies, particularly in the very high frequencies (the short-run cycles). Both fish oil and linseed oil prices are relatively flat, with the fish oil price spectrum containing a very weak two-year cycle and the linseed oil price spectrum showing cyclical activity at the four-year frequency.

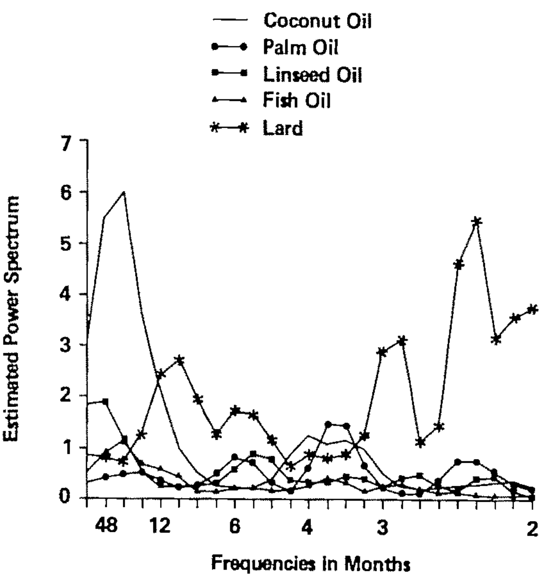


Figure 2. Estimated spectra of the prices of coconut, palm, linseed, and fish oils and lard

Coherence Estimates

Table 2 summarizes the coherence values at selected frequencies between selected pairings.[1] The criteria used is that coherence exceeding 0.50 is regarded as "moderate" and exceeding 0.75 is regarded as "high."

The four edible oil prices all exhibit high coherence among themselves in the lower frequency bands and moderate to high coherence in many of the annual or higher frequencies. The coherence pattern is strongest in the cottonseed oil-soybean oil price pairing where only one frequency contains a low coherence value. The coherence between rapeseed oil and the other three oil prices is in general less than for the pairings among the other oils.

Between soybean oil price and the palm oil prices, coherence values are high in the low frequency bands but there are only isolated instances of high or moderate coherence in the higher frequencies. Palm oil price is in general more highly correlated with soybean oil price than is coconut oil price, and this reflects the more specialized uses of coconut oil. Soybean oil price and linseed oil price exhibit high coherence in the low frequencies but only isolated instances of moderate coherence in the higher frequency bands. Between soybean oil price and lard and fish oil prices, the same overall pattern of coherence is evident with the price of lard showing a much stronger correlation.

Although not shown in table 2, coconut and palm oil prices are highly correlated in the lower frequencies and moderately correlated in the highest frequency band. Both the palm oil prices are highly or moderately correlated with lard and fish oil prices in the low frequencies with only isolated significant coherences in the other frequencies. Lard and fish oil prices are highly correlated in the low frequencies and at the annual frequency, and there are also moderate levels of coherence at several higher frequency bands. These types of patterns are also evident in the coherences between the price of linseed oil and lard, fish oil, and the palm oils.

On the basis of these results the first hypothesis is supported, i.e., the prices of oils and fats with similar characteristics and similar end uses are strongly interdependent, at least in the low frequencies. This is particularly evident within the edible oils. The corollary to this hypothesis is also supported, i.e., prices of fats and oils with dissimilar characteristics and different end uses are strongly independent. This is true of the relationships between the prices of coconut oil and soybean oil, and linseed oil and soybean oil.

To examine the second hypothesis, the data were split into two equal periods of 106 observations. The first period covered March 1959 to December 1967, and the second January 1968 to October 1976. It is recognized that 106 observations is less than that desirable for spectral analysis, but the results still should be useful, especially when the maximum number of lags used is small.

The coherence values for the two periods are reported in table 3 and the results are self-evident. In the earlier period, coherence values are at moderate or high levels in only the lower frequency bands and at only isolated instances in the higher frequencies. Coconut and palm oil prices are unrelated to soybean oil prices at all frequencies, and the same is true for the relationship between cottonseed and peanut oil prices. In the later period, however, coherence values rise dramatically and significant coherence values are evident at almost all frequencies. Even the prices of the palm oils are highly related to soybean oil prices in the low frequencies and moderately related at various higher frequency bands. On the basis of these results, the second hypothesis also is supported, i.e., price interdependencies have become more marked over time in markets with strong interchangeable demands.

Some of this effect must be related to the surge in prices in the early 1970s and the fact that all fats and oils responded to the shortages and surpluses of that period. Even though trend removal was effective, the influence of this price "bubble" has been so great that its total effects could not be filtered out of the data. However, the evidence that the in-

[1] To conserve space, not all pairings are reported and emphasis is placed on the edible vegetable oils and soybean oil in particular. Readers interested in a more complete tabulation may contact the authors.

Table 2. Coherence Statistics of Selected Fats and Oils, 1959–76

	Edible-Edible						Soybean-Others				
Cycles in Months	*PN*: *SOY*	*PN*: *RAPE*	*COT*: *PN*	*COT*: *RAPE*	*COT*: *SOY*	*RAPE*: *SOY*	*COC*: *SOY*	*PALM*: *SOY*	*SOY*: *LARD*	*SOY*: *FISH*	*LIN*: *SOY*
LR	.94	.83	.93	.81	.96	.84	.94	.93	.85	.93	.90
48	.84	.76	.86	.76	.88	.83	.75	.92	.63	.74	.84
12	.21	.07	.36	.26	.40	.56	.35	.59	.86	.74	.42
6	.72	.67	.80	.66	.74	.66	.14	.78	.84	.21	.79
4	.36	.18	.47	.66	.68	.48	.42	.43	.74	.42	.67
3	.49	.62	.51	.38	.93	.34	.19	.15	.73	.51	.35
2	.51	.73	.63	.61	.95	.51	.48	.39	.80	.11	.39

Table 3. Coherence Statistics, 1959–67 and 1968–76

Cycles in Months	Edible-Edible						Soybean-Others				
	PN: SOY	*PN: RAPE*	*COT: PN*	*COT: RAPE*	*COT: SOY*	*RAPE: SOY*	*COC: SOY*	*PALM: SOY*	*SOY: LARD*	*SOY: FISH*	*LIN: SOY*
	1st Period 1959–67										
LR	.56	.78	.45	.98	.84	.69	.22	.23	.91	.71	.26
48	.08	.23	.19	.43	.62	.75	.10	.10	.78	.46	.17
12	.29	.07	.08	.36	.16	.40	.16	.01	.53	.07	.15
6	.29	.13	.18	.03	.53	.04	.08	.14	.58	.12	.23
4	.34	.03	.23	.47	.09	.12	.08	.02	.29	.57	.02
3	.18	.40	.28	.15	.19	.01	.33	.03	.39	.11	.34
2	.29	.44	.27	.09	.51	.24	.08	.11	.25	.19	.98
	2nd Period 1968–76										
LR	.99	.99	.99	.94	.97	.99	.99	.99	.91	.99	.94
48	.95	.90	.97	.82	.92	.93	.86	.99	.67	.80	.92
12	.22	.10	.50	.34	.55	.75	.40	.72	.92	.85	.57
6	.75	.76	.86	.74	.78	.72	.30	.91	.89	.30	.89
4	.39	.26	.57	.76	.74	.58	.54	.53	.79	.49	.86
3	.55	.74	.56	.40	.97	.37	.25	.26	.75	.68	.48
2	.59	.88	.72	.67	.97	.59	.59	.64	.83	.21	.65

creased interdependencies extend into the very high frequencies provides justification for the view that the patterns of usage have changed because of hydrogenation, blending, and other improvements in processing technology. This means the edible vegetable oils, the palm oils, lard, and fish oil are now highly substitutable in their use. Soybean oil is now also more substitutable with linseed oil in industrial uses.

Gain Estimates

Table 4 lists the gain coefficients for selected pairings at the same selected frequencies. Gain (and phase) statistics provide very little useful information, however, if coherence is low (Parikh), so the gain (and phase) statistics are discussed in following sections only for those frequencies with high or moderate coherence values.

Within the edible oils, prices react to each other in approximately similar ways in the low frequencies although rapeseed oil price is more unstable than the others. At higher frequencies peanut oil and rapeseed oil prices show considerably greater stability than soybean oil or cottonseed oil prices. The price of palm oil is very stable relative to soybean oil price at most frequencies, but the price of coconut oil is highly unstable. For example, in the lowest frequency a given change in the price of palm oil is associated with a 174% change in the price of soybean oil, but a given change in the price of coconut oil is associated with only a 56% change in the price of soybean oil. In relation to the price of soybean oil, the price of linseed oil is seen to be relatively stable in the higher frequencies but relatively unstable in the low frequencies. Fish oil prices are very stable over all frequencies, and the price of lard exhibits a higher degree of stability

Table 4. Gain Statistics, 1959–76

Cycles in Months	Edible-Edible						Soybean-Others				
	PN: SOY	*PN: RAPE*	*COT: PN*	*COT: RAPE*	*COT: SOY*	*RAPE: SOY*	*COC: SOY*	*PALM: SOY*	*SOY: LARD*	*SOY: FISH*	*LIN: SOY*
LR	.90	1.23	1.07	1.35	1.01	.63	.56	1.74	.85	.67	.70
48	.86	1.17	.98	1.25	.98	.64	.42	1.70	.64	.72	.76
12	—	—	—	—	—	.89	—	1.37	1.36	.61	—
6	1.02	.72	.83	.67	.83	1.11	—	1.57	.75	—	1.87
4	—	—	—	.57	.77	—	—	—	.88	—	1.28
3	—	1.14	.43	—	.93	—	—	—	1.34	.33	—
2	1.21	.69	.38	.31	.80	1.50	—	—	1.26	—	—

than soybean oil price in the low frequencies but this pattern is reversed in the higher frequencies.

The prices of particular fats and oils, therefore, react in differing degrees to price changes in other fats and oils at various frequencies, so part one of hypothesis (c) is supported. For example, at the two-month frequency, soybean oil price reacts to cottonseed oil price changes by 80%, yet rapeseed oil price reacts by only 31%. At this frequency, then, cottonseed oil has a different impact on the soybean oil market than on the rapeseed oil market. Further, the reactions between the same two oil prices may vary over time. In the very high frequencies, lard prices react to soybean oil price changes by about 130%, yet at slightly lower frequency bands the price reaction is only 80%. This indicates that there may be some short-term price leveling behavior present; i.e., the price of a particular oil does not change by the full amount of a price change in a competing oil, but as time passes and the change appears to be enduring, then prices have to react by more than the initial change to compensate for the short-term maladjustments.

Phase Estimates

The phase statistics for the selected pairings and frequencies are reported in table 5. These statistics are in fractions of a circle. Applying the formula enables us to calculate the extent to which any two spectra are out-of-phase at any frequency, but we cannot distinguish whether these phase relationships are leads or lags except by using a priori information.[2]

Table 5 indicates that in the low frequencies there is a general lack of out-of-phase relationships. In the higher frequency bands, out-of-phase relationships become more widespread and more marked. Prices of oils within the same subclass are almost completely in phase, such as the edible oils (with the exception of rapeseed oil), as are prices of oils and fats in other subclasses that are very good substitutes, such as soybean oil and lard. Maximum out-of-phase relationships exist between the prices of fats and oils with different end uses, such as soybean oil, linseed oil, and fish oil.

The second part of hypothesis (c) is therefore supported as well; the price of particular fats and oils react differently through time to price changes in other fats and oils at various frequencies.

Conclusion

The high coherence values found cannot be interpreted as conclusive evidence of high substitutability among the various oils because other factors such as population and income growth simultaneously influence individual demand schedules and prices. However, it is probable that substitutability forms the largest component of these price relationships, especially in the short run. Of course what we would really like to know are the direct and cross-price elasticities of demand for the various oils. Unfortunately the high correlations among many of the oil prices make a direct measurement of the elasticities difficult although Labys (1977) has undertaken some analysis in this vein.

In any case the interrelationships are quite obviously not as simple as previous studies have inferred. In particular, the essential independence between the lauric oils and the other fats and oils prices found in previous studies may not now exist (Labys 1975, Nyberg). If the lauric oils cannot be regarded as a separate segment of the U.S. fats and oils complex, it has immediate implications for the feasibility of a lauric oils buffer stock currently being discussed in various international forums. Since the prices of most fats and oils seem to be highly interdependent, it may be relatively easy to manage the whole fats and oils complex by stabilizing the prices of just one or two of the major oils.

The statistics from cross-spectral analysis generate information about the relationships among variables that can be incorporated into econometric models of the international oilseed complex. For example, the coherence statistics are helpful in specifying the demand relationships within a model, because if coherence is low there is little explanatory power to be expected. Gain coefficients indi-

[2] The phase statistic at a particular frequency can be converted into a time shift by the formula $t = \gamma P$, where t is time shift in months; γ, phase in fraction of a circle; and P, period of the cycle at that frequency.

Table 5. Phase Statistics, 1959–76

Cycles in Months	Edible-Edible						Soybean-Others				
	PN: *SOY*	*PN*: *RAPE*	*COT*: *PN*	*COT*: *RAPE*	*COT*: *SOY*	*RAPE*: *SOY*	*COC*: *SOY*	*PALM*: *SOY*	*SOY*: *LARD*	*SOY*: *FISH*	*LIN*: *SOY*
LR	.97	.13	.02	.15	.99	.83	.07	.97	.03	.13	.97
48	.97	.17	.02	.19	.00	.80	.08	.96	.05	.15	.97
12	—	—	—	—	—	.18	—	.60	.06	.09	—
6	.05	.86	.96	.81	.99	.18	—	.11	.10	—	.70
4	—	—	—	.37	.95	—	—	—	.02	—	.51
3	—	.48	.97	—	.98	—	—	—	.01	.62	—
2	.06	1.00	.96	.92	.01	.11	—	—	.00	—	—

cate estimates of regression coefficients between any two fats and oils prices and may provide evidence for restricting coefficient values. Finally the phase statistics give estimates of the length of lags between different prices which may prove useful in specifying polynomial distributed lags. All this type of information is particularly helpful in models with potential degrees of freedom problems, i.e., models using scarce annual data and equations containing large numbers of explanatory variables.

[Received January 1978; revision accepted September 1978.]

References

Barksdale, H. C., J. E. Hilliard, and M. C. Ahlund. "Cross-Spectral Analysis of Beef Prices." *Amer. J. Agr. Econ.* 57(1975):309–15.

Boutwell, W., H. Doty, D. Hacklander, and A. Walter. *Analysis of U.S. Fats and Oils Industry to 1980.* USDA ERS-627, 1976.

Dixon, W. J., ed. *BMD Biomedical Computer Programs.* Berkeley: University of California Press, 1974.

Duncker, J. W. "World Price Behaviour of Edible Oils and Fats." *Can. Farm Econ.* 12(1977):14–22.

Food and Agriculture Organization (FAO). "Interchangeability of Individual Fats and Oils." *Approaches to International Action on World Trade in Oilseeds, Oils and Fats.* Rome: United Nations Commodity Policy Stud. 22, 1971.

Fishman, G. S. *Spectral Methods in Econometrics.* Cambridge, Mass.: Harvard University Press, 1969.

Granger, C. W. J., and M. Hatanaka. *Spectral Analysis of Economic Time Series.* Princeton, N.J.: Princeton University Press, 1964.

Houck, J. P., and J. S. Mann. *An Analysis of Domestic and Foreign Demand for U.S. Soybeans and Soybean Products.* University of Minnesota Agr. Exp. Sta. Bull. 256, 1968.

Houck, J. P., M. E. Ryan, and A. Subotnik. *Soybeans and Their Products: Markets, Models, and Policy.* Minneapolis: University of Minnesota Press, 1972.

Labys, W. C. "Dynamics of the International Lauric Oils Market." *Quantitative Models of Commodity Markets,* ed. W. C. Labys. Cambridge, Mass.: Ballinger Publishing Co., 1975.

———. "Multicommodity Substitution Patterns in the International Fats and Oils Market." *Europ. Rev. Agr. Econ.* 4(1977):75–84.

Nyberg, A. J. "The Demand for Lauric Oils in the U.S." *Amer. J. Agr. Econ.* 52(1970):97–102.

Parikh, A. "Study on Coffee Prices—A Spectral Approach." *Can. J. Agr. Econ.* 19(1971):15–25.

UNCTAD. *An Integrated Program for Commodities: The Role of International Commodity Stocks.* Geneva, Switz.: United Nations TD/B/C.1/166 Suppl. 1, 1974.

U.S. Department of Agriculture. *U.S. Fats and Oils Statistics 1961–76.* Econ. Res. Serv. Statist. Bull. No. 574 (and previous editions), 1977.

———. *Foreign Agriculture Circular: Oilseeds and Products.* FOP 12-77, 1977.

Vandenborre, R. J. *Economic Analysis of Relationships in the International Vegetable Oil and Meal Sector.* Dep. Agr. Econ. AERR-106, University of Illinois, 1970.

Trade Benefits to All: A Design of the Beef Import Liberalization in Japan

Yujiro Hayami

Liberalization of trade in agricultural commodities and protection of domestic agriculture are considered two conflicting policy goals. Severe restrictions have been imposed on the imports of agricultural commodities into Japan, resulting in substantial social costs, even though the level of agricultural protection in Japan is not necessarily higher than European Community (EC) countries (Bale and Greenshields, Hayami). The restriction is especially severe for beef where efficiency of domestic production is comparatively low. As a result, the expansion of beef imports has been a major focus in trade negotiations of Japan with Australia, New Zealand, and the United States.

In this paper, we argue that the basic premise of the present Japanese beef policy is wrong. As far back as Ricardo, trade liberalization has been shown to result in a net gain to society. Based on this logic, it should be possible to design a policy to achieve the dual goals of trade liberalization and the protection of domestic agriculture by redistributing the gains from trade. Our analysis suggests that a possibility exists for beef imports into Japan to increase several fold, to a level of $1 billion (U.S.) per year; and, at the same time, output and income of domestic producers also could be increased without imposing an additional burden on the government budget.

The Root of the Problem

Food prices in Japan generally are high relative to other developed countries, reflecting Japan's comparative disadvantage in agriculture (table 1). The price of beef is especially high; the retail price of beef in Tokyo is seven to nine times higher than in the capitals of Australia and the United States and three to five times higher than EC capitals.

Corresponding to price differentials, there are large differentials in the levels of beef consumption (table 2). Average per-capita protein intake in Japan from beef is less than one-tenth that of Australia or the United States, and less than one-fifth of the EC countries. The proportion of beef as a source of animal protein is also low in Japan in comparison with other countries.

The low level of beef consumption in Japan is, to a large extent, explained by traditional food consumption habits that rely heavily on fish as a protein source. But, considering the fact that beef is a commodity of high income elasticity and that Japan's per-capita income has exceeded Italy and the United Kingdom, the low level of beef consumption cannot be explained without large price distortions.

It is obvious, of course, that beef imports are severely restricted to protect inefficient domestic production. Traditionally, beef has been a by-product of draft power. Cattle were used as draft animals for several years and then fattened and sold for meat. As a by-product, feeder-cattle have been available at relatively modest cost.

However, when tractors substituted for the draft animals from the late 1950s to the early 1960s, the Japanese beef industry lost the cheap feeder cattle supply. Since the late 1960s, the fattening of dairy steers (Holsteins or Fresians) has developed and is now supplying nearly 60% of domestic beef. The average size of dairy steer operations has expanded rapidly.

Yet, the average size of the beef cattle raising and feeding unit in Japan is still very small, less than five cattle per farm (a total of two million cattle raised and fed by 450,000 producers). A majority of cattle raisers live in remote depopulated areas, typically raising one or two *wagyu* (traditional Japanese breeds) as a sideline of subsistence farming. The productivity of such operations is inevitably low and the cost high.

The present levels of beef consumption and prices are abnormal, not only in international comparison but also in historical comparison. In 1960, the levels of consumption were about the same for beef and pork, corresponding to the same price levels. However, in the process of "miraculous" economic development in Japan, the price of beef rose sharply relative to the price of pork, resulting in a drop in the consumption of beef relative to pork (table 3).

The major factor behind the rise in beef prices relative to pork prices was a lag in technological development to exploit economies of scale. While

---

Yujiro Hayami is a professor of economics at Tokyo Metropolitan University, Japan.

This paper is based on the study at Seisaku Koso Forum (Forum for Policy Innovation), a voluntary group of social scientists in Japan. Its summary in Japanese was released as the policy proposal of the Forum at the press briefings on 19 April and 23 June 1978. The proposal was propagated extensively in Japan through papers, radio, and TV, and was discussed at various levels including the National Diet.

The author is indebted to suggestions and comments from John Longworth and John Wicks as well as Forum members.

Table 1. International Comparison of Retail Food Prices, 2 November 1977

	Ratios of Tokyo Prices to Prices in Other Capitals[a]							
Country	Beef, Sirloin, Boneless	Pork, Chops	Broilers	Eggs	Butter	Milk	Bread, White	Rice
Australia (Canberra)	8.7	1.9	1.5	1.0	2.6	2.0	1.3	1.6
United States (Washington)	7.2	1.6	3.0	1.5	1.7	1.8	1.1	1.7
France (Paris)	4.6	—	1.7	0.8	1.4	2.3	1.1	1.1
Germany (Bonn)	3.3	1.3	1.6	0.9	1.6	2.0	1.6	0.7
Italy (Rome)	4.2	1.6	1.3	0.9	1.4	2.1	1.7	1.0
United Kingdom (London)	4.9	2.0	2.1	1.3	2.6	2.5	2.0	1.4

Source: U.S. Department of Agriculture, pp. 6–7.
[a] Calculated after converting into U.S. dollars by current exchange rates at the time of the survey.

the other meat-producing sectors, such as pigs and broilers, have developed a system of large-scale, labor-saving operations based on imported feed grains, the beef sector has been constrained by the inability to develop an efficient supply of feeder cattle. This is partly because of the scarcity of land in Japan and partly because of the difficulty of transforming the traditional *wagyu* operations into modern enterprises.

Irrespective of the low production efficiency, cattle breeding is a critical source of income for farmers in poverty areas. Because electoral votes in such poor, depopulated districts are over-represented in the National Diet, political necessity as well as welfare considerations require the protection of the domestic beef industry. To protect the domestic producers, the government supports the domestic wholesale price of beef within a "price stabilization zone" of floor and ceiling prices. The policy instrument used to maintain beef prices within the zone is the control of supply by means of an import quota (Longworth 1976, 1978).

Currently, all beef imports (except a less than 10% private quota) are monopolized by the Livestock Industries Promotion Corporation (LIPC). A typical cost structure for imported beef in 1977 in the case of Australian grass-fed chilled beef in a boneless beef form was: (*a*) an FOB export price of

Table 2. International Comparison of Animal Protein Consumption per Capita

	Per-Capita Protein Intake (g/day)					Ratio of Beef (%)	
	Meat						
	Beef A	Total B	Eggs and Dairy	Fish	Total C	A/B	A/C
1964–66 average:							
Australia	14.8	33.2	24.5	3.1	60.8	45	24
United States	17.3	34.5	29.0	3.2	66.7	50	26
France	11.0	27.9	22.8	5.7	56.4	39	20
Germany	9.0	23.9	23.5	3.4	50.8	38	18
Italy	7.4	14.1	16.6	3.4	34.1	52	22
United Kingdom	7.4	23.1	25.5	4.3	52.9	32	14
Japan	0.8	4.8	6.2	14.5	25.5	16	3
1973:							
Australia[a]	(17.9)[b]	39.8	27.9	1.7	69.3	—	—
United States	(19.5)	39.0	31.1	2.5	72.6	—	—
France	(13.3)	34.1	27.9	5.0	67.0	—	—
Germany	(10.8)	28.5	25.5	3.5	57.5	—	—
Italy	(12.5)	24.0	21.1	3.6	48.7	—	—
United Kingdom	(8.0)	24.9	27.3	2.4	54.6	—	—
Japan	1.2	8.7	9.2	17.0	34.9	14	3
1976:							
Japan	1.4	9.5	9.3	17.5	36.3	15	4

Source: FAO; OECD; and Japan Ministry of Agriculture and Forestry, Minister's Secretariat, Research Section, 1977.
[a] 1972.
[b] Estimated by assuming the same (A/B) ratios as for 1964–66.

Table 3. Changes in Prices and Per-Capita Consumption of Beef and Pork in Japan

	Prices in Tokyo				Average Per-Capita Consumption (kg/year)	
	Wholesale (yen/kg)[a]		Retail (yen/100 g)[b]			
	Beef	Pork	Beef	Pork	Beef	Pork
1960	287	346	55	64	1.1	1.1
1965	484	366	96	79	1.5	3.0
1970	630	367	148	88	2.1	5.3
1975	1,260	692	268	153	2.6	7.3
1976	1,462	674	292	161	2.7	7.7
1977 (December)	1,503	660	312	161		

Source: Japan Ministry of Agriculture and Forestry, Division of Statistical Information; and Minister's Secretariat, Research Section, 1977.
[a] Averages in dressed carcass weight.
[b] Cut meat, median grade.

450 yen per kilogram; (*b*) a CIF import price of 520 yen per kilogram; (*c*) the procurement cost for LIPC, which added the 25% ad valorem tariff to the CIF price of 650 yen per kilogram; and, finally (*d*) the sale price from LIPC was about 1000 yen per kilogram, which added to the procurement cost the import levy of 350 yen per kilogram (raised to 600 yen since October 1977).

This LIPC sale price of imported beef was much lower than the midpoint price of the price stabilization zone for domestic beef from dairy breeds. That was 1235 yen per kilogram in dressed carcass or nearly 2200 yen per kilogram in boneless beef, assuming a conversion factor of 0.6 and a 5% processing cost.

Even though domestic beef from dairy breeds that undergo a fattening process is better in quality than imported grass-fed beef and can command higher prices by 30% to 40%, there still exists a large gap between the LIPC sale price of imported beef and the domestic beef price at the wholesale market. As a result, wholesalers who are licensed to purchase imported beef from LIPC easily can earn large profits; this problem has recently become an issue at the National Diet.

Designing a Trade Liberalization Program

For the plan to liberalize beef imports to be feasible, domestic producers must be protected and at the same time too much burden must not be imposed on the government budget. To satisfy those requirements one policy might be deficiency payments, thus abolishing the import quota and financing deficiency payments from a levy imposed on imports.[1]

[1] This policy is suboptimal. Theoretically the Pareto optimality can be achieved by abolishing tariff and levy and financing deficiency payments from general tax revenue. However, considering political difficulties involved in raising general tax revenue and in increasing its share to agriculture, it does not seem feasible to adopt the Pareto-optimum solution.

The domestic price of beef would be reduced drastically by removing the import quota. However, a sudden, large-scale reduction of prices likely would cause disruptions in both domestic and international markets. The target for the first-round trade liberalization program could be set to abolish the import quota and to cut down gradually the initially raised tariff and levy rates to a level of 550 yen per kilogram (25% ad valorem tariff plus a levy of 350 yen/kg) over five to seven years. The transition period required and the optimum schedule of tariff cuts within the period will, to a large extent, depend on the speed by which world beef production will increase corresponding to an increase in Japanese demand. At this stage we do not have sufficient information to specify the period and the schedule rigorously. The period of five to six years is assumed here mainly for the sake of illustration and it is difficult to specify the concrete schedule of tariff cuts. This paper aims to suggest a direction of policy change. A large-scale research at the government level will be necessary to design a more concrete plan.

Model

What effects will be produced from the adoption of the trade liberalization program? The model used to estimate the effects is shown in figure 1. Here, *dd* and *ss* respectively represent domestic demand and supply. A market equilibrium under the present system is established at B. The import is restricted to the quantity $Q_dQ_0(= q_0 - q_d)$, so that the domestic price is maintained at a level $OP_0(= p_0)$. As the new policy is adopted, the domestic price will be reduced to $OP_1(= p_1)$, which is higher than the import price $OP_w(= p_w)$ by the rate of tariff and levy $P_wP_1(= t)$.

The benefit and the cost associated with the adoption of the new policy can be measured as follows. The deficiency payment cost is $ACP_1P_0 =$

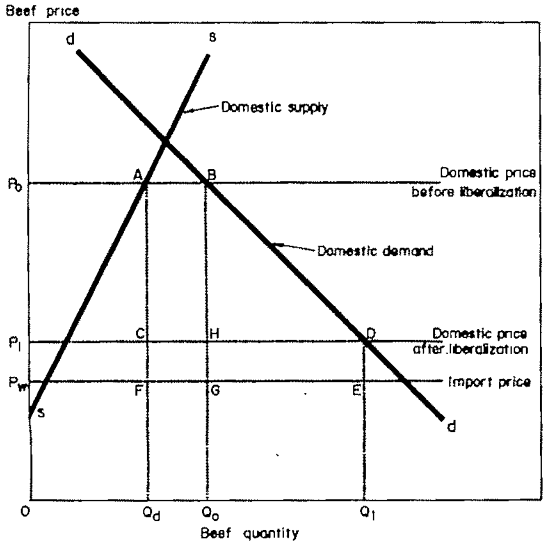


Figure 1. Effects of beef import liberalization

$q_d(p_0 - p_1)$. The tariff and levy revenue is $DEFC = t(q_1 - q_d)$. The increase in consumers' surplus is

$$BDP_1P_0 = \frac{1}{1-\eta}(p_0q_0 - p_1q_1) \text{ for } \eta \neq 1, \text{ and}$$

$$BDP_1P_0 = p_0q_0(ln\ p_0 - ln\ p_1) \text{ for } \eta = 1.$$

Thus, the net social benefit is

$$DEGB = DEFC + BDP_1P_0 - (ACP_1P_0 + BGFA),$$

where the domestic price and the consumption after the trade liberalization are given respectively as,

$$P_1 = P_w + t, \text{ and}$$

$$q_1 = q_0\left(\frac{p_1}{p_0}\right)^{-\eta},$$

if a constant price elasticity of demand for beef (η) is assumed.

Demand and supply in figure 1 are assumed as the schedules at a wholesale level. It might be argued that consumers' surplus should be measured at a retail level and the cost of deficiency payment be measured at the farm gate. However, for constancy in marketing and processing costs, demand and supply at both retail and farm gate levels can be represented by parallel shifts from those of the wholesale level. With this assumption, consumers' surplus and the cost of deficiency payment can be measured approximately from the demand and supply schedules at the wholesale level.

Assumptions

How much will the domestic price of beef decline with the abolition of import quota while maintaining the rate of tariff and import levy at a level of 550 yen per kilogram? First, assume that the domestic beef produced from the fattening of dairy steers is the same in quality as the grain-fed chilled beef from the United States. The CIF price of U.S. chilled beef is about 800 yen per kilogram in boneless beef at Japanese ports. Adding tariff, levy, and other miscellaneous costs, imported chilled beef can be supplied to the wholesale market at about 1400 yen per kilogram. An unlimited supply of imported beef at this price will result in a decline of the domestic wholesale price from 2200 yen per kilogram for boneless beef (1235 yen per kilogram in dressed carcass) to 1400 yen per kilogram.

Assuming that domestic production will be maintained at the present level by the deficiency payments, the increase in the quantity of beef import will depend on the increase in consumption corresponding to the price fall. The price elasticity of demand for beef was estimated as 1.6 by Yuize using a simple regression in a double-log form. The estimates by the research section in the secretariat of the Ministry of Agriculture and Forestry range from 1.5 to 1.8. An estimate by Sawada using Theil's system of demand equations was 1.3. A recent study by Uchiyama using the Koyck-Nerlove model resulted in an estimate of a short-run elasticity of 0.6 and the estimate of a long-run elasticity of 2.2. From those results the price elasticity of beef demand of 1.5 seems a reasonable figure to apply to the estimation of the effects of a secular price decline due to trade liberalization. The calculations have employed both 1.5 and 1.0 to investigate the sensitivity of the results.

The quantities of domestic beef output and consumption at present are roughly 180,000 metric tons and 280,000 tons, respectively. Those quantities will change during the transition period of our program, which is assumed to be about five to seven years. Suppose that the program will be completed six years from now. It is projected rather radically that at the year of completion the domestic output will be expanded to 260,000 tons at a rapid rate of 6% per year.[2] It is also projected that even in the absence of the trade liberalization program, domestic consumption will increase to 430,000 tons six years from now, assuming that the average annual growth rate of real income per capita will be 5% and the income elasticity of beef demand is 1.5.

Estimation Results

The results of estimation of the costs and benefits associated with the beef trade liberalization plan under proposal are shown in table 4. The estimation

[2] It is assumed that the output growth rate for the next six years will be doubled from the past six years by the government efforts to expand domestic beef production. The probability that such high rate of growth acceleration can be achieved is rather small. The somewhat unrealistic rate is assumed here in order to obtain lower-bound estimates for the benefits from the trade liberalization program.

Table 4. Estimation of Benefits and Costs Associated with the Beef Trade Liberalization

	At Present		At the Completion of the Plan	
	$\eta = 1.5$	$\eta = 1.0$	$\eta = 1.5$	$\eta = 1.0$
Domestic output (10,000t) q_d	18	18	26	26
Domestic consumption before liberalization (10,000t) q_0	28	28	43	43
Import before liberalization (10,000t) $q_0 - q_d$	10	10	17	17
Domestic price before liberalization (yen/kg) P_0	2,200	2,200	2,200	2,200
Domestic price after liberalization (yen/kg) P_1	1,400	1,400	1,550	1,550
Domestic consumption after liberalization (10,000t) $q_1 = q_0 \left(\frac{P_1}{P_0}\right)^{-\eta}$	56	45	73	60
Import after liberalization (10,000t) $q_1 - q_d$	38	27	47	34
Deficiency payment (100 million yen)	1,440	1,440	1,690	1,690
Tariff and levy (100 million yen)	2,090	1,480	2,580	1,870
Increase in consumer surplus (100 million yen)	3,360	2,780	3,710	3,310
Net social benefit (100 million yen)	2,660	1,480	2,570	1,450

Note: All quantities and prices are expressed in terms of boneless beef.

was made for four different assumptions. The first two cases assume that the program is executed at present demand and supply relations. The latter two cases assume that the program is executed at the demand and supply relations that are expected to prevail six years from now when the liberalization program will be completed. In the latter cases, not only higher levels of domestic output and consumption are assumed, reflecting the rightward shifts in both demand and supply, but also the domestic price after liberalization is assumed to rise due to a possible increase in the import price of beef in response to the increased purchase from Japan. For each assumption, two alternative estimates of the price elasticity of beef demand (η) are applied.

The results show that in all four cases the cost of deficiency payments for domestic beef producers will be more than covered by the revenue from tariff and levy on imported beef. Thus, both domestic output and income of producers can be maintained without an added burden on the government budget.

Obviously, domestic consumers are the major beneficiaries from the trade liberalization program; their gain in the form of the increase in consumers' surplus will amount to 300 to 400 billion yen (about 1.5 to 2 billion U.S. dollars) per year. Net social benefit from the liberalization plan also will be very large, ranging from 150 to 250 billion yen; such a large benefit must exceed by a wide margin any possible increase in the administrative cost of the deficiency payment scheme.

Possible Problems

The effects of the beef trade liberalization program have been estimated within a framework of Marshallian partial equilibrium analysis. It may be suspected, however, that in reality the decline in beef prices corresponding to increased imports will affect adversely the demand for other livestock products, resulting in a decline in the incomes of domestic pork and chicken producers.

According to Sawada, cross elasticities of demand for pork and chicken with respect to the price of beef are 0.5 and 0.2. Those estimates suggest that adverse effects of the beef import liberalization program on pork and chicken sectors can be quite large. In Japan, however, such adverse effects likely will be cancelled out by the increase in the price of fish, a major source of animal protein for the Japanese. For more than a decade, the price of fish has increased much faster than the price of meat, resulting in a doubling of the relative price of fish to meat within a five-year period. Such trends likely will continue in the future, because the cost of fish supply will rise due to the primary resource limitation.

Sawada's estimates of the cross elasticities of demand for pork and chicken with respect to the price of fish are 0.4 and 0.3. Thus, the adverse effects of the beef trade liberalization on the demand for pork and chicken will be largely cancelled out by the rising price of fish within five to seven years before the liberalization program will be

completed. Further, since per capita income is expected to rise at 5% per year and the income elasticity of demand for meat as a whole is higher than 1.0, the demand for pork and chicken will continue to rise rapidly despite the possible adoption of the beef trade liberalization program.

Another possible difficulty would be the limitation of the capacity of world beef supply to Japan. The plan under proposal will require an additional beef import to Japan in the order of 200,000 to 300,000 tons, about 10% of the total beef import in the world. An additional demand in such a scale might cause a disruption in the world beef market and, as a result, Japan might have to import beef at a much higher price than assumed in this study.

This problem does not seem so serious in the long run. Suppose that Australia, which has now an 80% share of Japanese beef import, will have to supply an additional 200,000 tons. This quantity is about 10% of beef output in Australia. According to Wicks and Dillon, the price elasticity of beef supply in Australia is about 0.8 in an intermediate run (five to ten years). Then, the additional supply of 200,000 tons to the Japanese market will require a price increase by only about 12%.

In the short run, however, it is likely that the world price would skyrocket if Japan attempted a large-scale beef import without due considerations of world supply and demand conditions. In order to avoid disruptions in the world market, beef trade liberalization in Japan would need to be scheduled and executed carefully with deliberate coordination with major exporting and importing countries.

Conclusion

This paper has attempted to outline a feasible plan to liberalize beef trade in Japan. The results suggest that a policy can be designed to produce large benefits for both domestic consumers and foreign suppliers without worsening the position of domestic producers and without imposing an additional burden on the government budget. The basic premise of present policy—that the interests of domestic consumers and exporting countries necessarily conflict with those of domestic producers—has no ground. All parties can gain by adequately redistributing gains from international trade.

It should be cautioned, however, that the plan proposed in this study to combine trade liberalization and the deficiency payment may not be applicable to all commodities in all countries. In Japan, the degree of trade restrictions on beef is so high that domestic prices are abnormally high and consumption is abnormally low. In such a situation, the reduction of restrictions will result in a large net benefit to society that will clearly exceed the cost of instituting and managing the deficiency payment scheme. For commodities for which the consumption is near to saturation, such as rice, the net benefit from trade liberalization may not pay for the additional administrative cost.

[Received July 1978; revision accepted December 1978.]

References

Bale, Malcolm D., and Bruce L. Greenshields. "Japanese Agricultural Distortions and Their Welfare Value." *Amer. J. Agr. Econ.* 60(1978):59–64.

Food and Agriculture Organization (FAO). *Food Balance Sheets 1964–1966*. Rome, United Nations, 1968.

Hayami, Yujiro. "Nosanbutsu Boeki Jiyuka no Sekkei (Designing the Agricultural Trade Liberalization)." *Gendai Keizai* 31(1978):62–79.

Japan Ministry of Agriculture and Forestry, Division of Statistical Information. *Shokuniku Ryutsu Tokei* (Meat Marketing Statistics). Tokyo, various issues.

Japan Ministry of Agriculture and Forestry, Minister's Secretariat, Research Section. *Shokuryo Jyuyo Bunseki* (Food Demand Analysis). Tokyo, 1971.

———. *Showa 51 Nendo Shokuryo Jyukyu Hyo* (Food Balance Sheets 1976). Tokyo, 1978.

Longworth, John W. "Institutions and Policies Influencing Japanese Beef Import." *Rev. Mktg. and Agr. Econ.* 44 (1976):19–43.

———. *The Japanese Beef Market: Recent Developments and Future Policy Options*. University of Queensland Agricultural Econ. Disc. Pap. 3/8, 1978.

Organization for Economic Cooperation and Development (OECD). *Food Consumption Statistics 1955–1973*. Paris, 1975.

Ricardo, David. *On the Principles of Political Economy and Taxation*, ed. Piero Sraffa. Cambridge: Cambridge University Press, 1951.

Sawada, Yutaka. *Nikurui Juyo Hendo no Keiryo Teki Bunseki* (Econometric Analysis of Meat Demand). Mimeographed. Prepared for the 1976 annual meeting of the Japan Agricultural Economics Society. Tokyo, 1976.

Uchiyama, Toshinori. *An Analysis of Meat Consumption by a Dynamic Model*. Fukuoka University Agr. Econ. Work. Pap. No. 12. Fukuoka, Japan, 1978.

U.S. Department of Agriculture. *Foreign Agriculture*. 12 Dec. 1977.

Wicks, John A., and John L. Dillon. "APMAA Estimates of Supply Elasticities for Australian Wool, Beef and Wheat." *Rev. Mktg. and Agr. Econ.* 46(April 1978):48–57.

Yuize, Yasuhiko. *Shokuryo Keizai no Bunseki* (The Analysis of Food Economy). Tokyo: Dobunshoin, 1971.

Distributional Aspects of Price Intervention

Malcolm D. Bale

For a small country, whose terms of trade are beyond its control, the loss of welfare (real income) associated with price intervention policies, such as international trade restrictions, is often calculated by the summation of producer and consumer "deadweight losses" in a Hicksian-compensated economic surplus framework.[1] Such calculations presumably are useful to policymakers in their decision making. Yet frequently, an important part of the analysis, namely the internal redistributive effects of the policy, is neglected. These effects are often large and are equally important in the policy decision process. Such is the case in a recent *Journal* article by Bale and Greenshields (hereafter referred to as BG). They present an analysis of the welfare costs of current and future Japanese trade and production policies of major agricultural commodities produced and imported by Japan. The real income loss and proportion of food expenditure represented by the calculations, while impressively large, pale in comparison to the distributive effects of such policies. In this note the redistribution of real income between Japanese consumers and producers and the government revenue effect, using the BG data, will be presented together with a brief discussion of distributional effects.

Domestic Distribution Effects

When price intervention is undertaken by government, a domestic reallocation of income occurs. Usually the reallocation is a secondary consequence of the policy; some of the primary reasons touted are regional and industrial development, protection from foreign competition on security or infant industry grounds, and so on. Unlike pricing policies of individual firms, government pricing policies are likely to have a significant effect on private investment, resource allocation, production and consumption patterns, and trade. Thus, through the growth process they have a long-term impact on the entire direction of the economy. By systematically comparing domestic prices and international prices of close substitutes, the compatibility between instruments and targets of government policy can be evaluated. Unless this is done, the ultimate result will be that through a series of ad hoc policy decisions, a fragmentary, confusing, and conflicting set of price distortions will evolve over time.

The use of price intervention in the context of the Japanese agricultural sector is justified in terms of food security—world agricultural price instability, vulnerability to trade embargoes, and the like. Producer price supports via such devices as input subsidies, government purchasing, tariffs, and quotas provide production incentives to private operators; while high consumer prices tax consumption, thus reducing the dependency on imports.[2] But the costs and benefits are not evenly (or equally) distributed within those broad categories. Large-scale farmers buy most of the subsidized inputs and produce most of the price-supported output. Small farmers use fewer purchased inputs and produce only a small amount of output.[3] Likewise, the costs to consumers are unevenly borne. Consumers in the lower income brackets bear a disproportionate burden in that a larger portion of their income is spent on food than is the case with wealthier consumers. Thus, the effect of price intervention is not only to transfer income from consumers to producers, but also to skew income distribution categories.

The redistribution of national income from consumers to producers and the government-revenue effect, using the BG notation, can be shown as follows: the producer gain in welfare, Δp, is

$$Q'_d(P'_d - P'_w) - \tfrac{1}{2}(P'_d - P'_w)(Q'_d - Q'_w),$$

while consumers forfeit income, Δc, of

$$Q_d(P_d - P_w) + \tfrac{1}{2}(P_d - P_w)(Q_w - Q_d)$$

and government revenue, G, is

$$Q_d(P_d - P_w) - Q'_d(P'_d - P'_w),$$

where P_w and P'_w are border price (world price) at

Malcolm D. Bale is an economist, World Bank, and a professorial lecturer at Johns Hopkins University.

The author wishes to thank Ernst Lutz and an anonymous reviewer for helpful comments on an earlier draft. The views expressed are those of the author and not necessarily those of his affiliates.

[1] The small country assumption where terms of trade are taken as constant is implicit in the Corden framework and has been widely accepted in empirical studies (for example, Dardis). In his pathbreaking work on the "scientific tariff," Johnson initially assumed no terms of trade effects and later qualitatively included them. In the case of Japanese imports of agricultural goods, it is likely that Japanese import restrictions have, at most, a marginal positive effect on their terms of trade and that the operational assumption employed here of constant terms of trade is not a serious shortcoming.

[2] These policies are equivalent to a partial devaluation of the yen and therefore contribute to the large balance-of-payments surplus that Japan is experiencing.

[3] For example, small farmers cannot benefit from subsidies on four-wheel tractors because of the lumpiness of the input.

retail and producer levels, respectively; P_d and P'_d are domestic retail and producer prices, respectively; Q_d and Q_w are domestic consumption at domestic prices and world prices, respectively; Q'_d and Q'_w are domestic production at domestic prices and world prices, respectively. Using these formulas together with the BG estimations, the distribution and revenue effects of Japanese agricultural price intervention policies are calculated.[4]

Estimated Distribution Effects

Table 1 presents the consumer losses and producer gains by commodity in 1975/76 and the producer gains if the goals of the 1985/86 Japanese National Food Supply Program were implemented in 1975/76. Also, government revenue (received or distributed) for the two scenarios is given. As is assumed in the earlier work, prices in 1985/86 are based on 1975/76 prices. As can be seen, the magnitude of the redistribution is large—often more than ten times the size of the net social losses calculated in BG (reproduced as column 1 of table 1). Rice, the cornerstone of Japan's food policy, is the commodity where, in 1975/76, the largest redistribution occurred. Support prices paid by the government to farmers were more than twice the level of world rice prices. To maintain consumption, a subsidy was paid on rice; yet the domestic retail price was still above that of the retail border price. As a consequence, over 1.5 trillion yen were allocated to rice producers, with nearly one trillion yen coming from consumers and over 600 billion yen coming from government outlays. In keeping with current Japanese policy of maintaining total rice consumption at approximately 1975/76 levels and lowering production to that level, it is assumed for analytical purposes that producer rice prices are held at current levels and production controls are tightened. This approximates Japanese rice policy since 1971. Since the 1985/86 goals require reduced rice production, the transfer of income from government to rice producers is reduced with the achievement of the 1985/86 goals. Rice is the only commodity where such a reduction occurs.

The general pattern for 1975/76 was that for the eight agricultural commodities, national income was redistributed from consumers to producers and government. The size of the redistribution dwarfs the reduction in national income caused by the policy. In this case, it can be argued that the redistribution effects have a more dramatic impact on the growth and direction of the economy than does the efficiency loss. As noted earlier, the distribution of costs and benefits within the categories is not necessarily equal. Farmers engaged in rice production received the largest transfer in the 1975/76 exercise, while livestock enterprises receive large inflows in the 1985/86 scenario. Further, although government collects tariff revenue on most products, the government revenue effect is not neutral. It can be seen from table 1 that in 1975/76, government revenue was used to supplement consumer transfers to cereal producers. The government did, however, record a net gain of 465 billion yen from its agricultural price intervention activity. The spectacular change in government reallocations if the 1985/86 goals were implemented can be seen in

[4] Japan, of course, is not alone in pursuing policies which cause redistribution of national income from consumers to producers. Most developed countries, such as those in the European Community, Switzerland, and the United States, have various agricultural policies which affect such a redistribution. It is interesting to compare this policy with agricultural policies in many developing countries where the opposite redistributions are made. By agricultural export taxes and low domestic prices for foreign aided food imports, national income is redistributed from agricultural producers to consumers. See Lutz and Scandizzo.

Table 1. Consumer Losses, Δc, Producer Gains, Δp, and Government Revenue, G, of Selected Agricultural Commodities in Japan

	NSL (1975/76)	Δc (1975/76)	Δp (1975/76)	Δp (1985/86)	*G* (1975/76)	*G* (1985/86)
	(billion yen)					
Wheat	0.50	−54.19[a]	13.45	25.56	−68.14	−105.80
Rice	25.80	931.83	1,513.67	1,390.58[c]	−607.64	−468.04
Soybeans	0.75	193.98	6.63	397.20	186.60	−452.55
Barley	4.85	−29.15[a]	8.06	97.88	−42.06	−226.57
Milk	41.97	375.69	116.08	733.40	217.64	−566.19
Pork	27.50	533.12	146.03	5,623.47	359.59	−6,236.30
Chicken	1.05	157.84	−24.74[b]	2,601.48	181.53	−2,703.78
Beef	14.50	314.82	62.81	1,022.76	237.50	−1,087.00
Total	116.98	2,423.94	1,841.94	9,136.11	465.02	−11,846.23
	(million dollars)[d]					
Total	387	8,026	6,099	30,252	1,540	−39,226

[a] In the case of wheat and barley consumers gain because of Japanese pricing policies.
[b] Chicken producer prices in 1975/76 were below border prices.
[c] For rice, current prices and production controls are assumed. See text for details.
[d] Dollar-yen exchange rate (1975/76) is 1:302, as used by BG.

column 6, table 1. Transfers from government to producers occur for every commodity considered, with livestock production receiving the lion's share. The cost to consumers through both the direct consumer transfers and the indirect Japanese treasury transfers amounts to over $47 billion. Clearly such distribution effects have a profound dynamic impact on the economy in terms of altered consumption patterns, distorted growth, and multiplier effects which ripple through the entire economy. While Japanese agricultural policy is formulated for specific reasons, policymakers require the foregoing information in order to understand the consequences of their policy actions.

[*Received August 1978; revision accepted January 1979.*]

References

Bale, M. D., and B. L. Greenshields. "Japanese Agricultural Distortions and Their Welfare Value." *Amer. J. Agr. Econ.* 60(1978):59–64.

Corden, W. M. "The Calculation of the Cost of Protection." *Econ. Record* 33(1957):129–48.

Dardis, R. "The Welfare Cost of Grain Protection in the United Kingdom." *J. Farm Econ.* 49(1967):597–609.

Johnson, H. G. "The Cost of Protection and the Scientific Tariff." *J. Polit. Econ.* 68(1960):327–45.

Lutz, E., and P. L. Scandizzo. "Price Distortions in Developing Countries: A Bias against Agriculture." Mimeographed. Washington, D.C.: Agr. and Rural Develop. Dep., World Bank, 1978.

Risk Management in Imperfect Markets: Commodity Procurement Strategy in the Food Manufacturing Sector

Marvin L. Hayenga

Analyses of firm behavior in imperfect markets typically have stressed the nature of competition in the output or product markets, with little attention to a firm's input market behavior, its relation to product market structure, and its corresponding impact on the firm's financial performance and competitive viability. In this paper, attention is focused on the input market behavior of food-manufacturing firms operating in imperfect market structures. We briefly consider the nature of the input market environment and the procurement options available for the most important inputs in most food-manufacturing firms—agricultural commodities. Following that, the complex factors which simultaneously affect the firm's commodity procurement strategy are explored. While internal firm considerations—financial viability, product diversification, and management objectives—are briefly discussed, primary emphasis is placed on the product market structure in which the firm is competing and its influence on commodity procurement strategy. Some interrelationships between product market structure and input market behavior are postulated, and their implications for product price levels and volatility are suggested.

Theoretically, a firm would be expected to minimize the unit cost of raw materials purchased in order to maximize its profits and survive in a perfectly competitive environment. But food-manufacturing firms deal in volatile and uncertain commodity markets and in imperfect market structures where the actions of rivals in commodity (input) markets and product (output) markets may influence significantly the firm's optimal procurement strategy and overall performance. Kaysen has suggested that "the firm in the less competitive market can choose whether to seek maximum profit or to be satisfied with some 'acceptable' return and to seek other goals. . . . The more dominant the position of any particular firm in a single market . . . the wider will be its range of significant choice" (p. 90). We shall explore whether a similar line of reasoning seems appropriate in explaining the commodity procurement behavior of food-manufacturing firms, as we consider the complex of factors that would be relevant in developing a game theory or similar risk-management model for firms in a variety of imperfect product market settings.

Marvin L. Hayenga is a senior economist, North Central Regional Research Project 117, and visiting professor, University of Wisconsin.

The Commodity Procurement Decision Process

In recent years, the volatility of prices in world commodity markets—record price levels have been achieved in one commodity or another almost every year in the early and mid-1970s—has caused the commodity procurement decision to be increasingly important in food-manufacturing firms.

Food-manufacturing firms have the option of (*a*) establishing their commodity unit cost (purchase price) at the time of use, or very close to it ("hand to mouth" purchasing); or (*b*) taking a market position in advance of the time of use, establishing the unit cost of some or all of their anticipated commodity requirements through futures markets (anticipatory hedging), fixed-price purchase contracts with suppliers, or advance purchase and storage of the commodity.

In markets where significant price fluctuations are frequent, the timing of commodity purchases has a significant influence on the firm's costs. Key elements in the decision must include the forecast probability distribution of the relevant cash and future delivery commodity price levels (and their "basis" relationships) over the time period prior to use, the key contingencies or environmental factors (weather, government policy changes, etc.) affecting those probabilities, the typical distribution of forecast error, and the current cash and future contract prices.

In most commodity markets, an accurate assessment of the probability distribution of future commodity price levels is quite difficult but, whether considered explicitly or implicitly in the decision process, it is critical in effective risk management for firms facing volatile commodity markets. In figure 1, the expected probability distribution of commodity prices which will be available to the firm in future time periods is illustrated; prices in more distant time periods are portrayed with a larger variance, reflecting the greater number of factors influencing prices which have not yet been determined (e.g., domestic and foreign crop production). By taking commodity prices presently available for current and future delivery, and over-

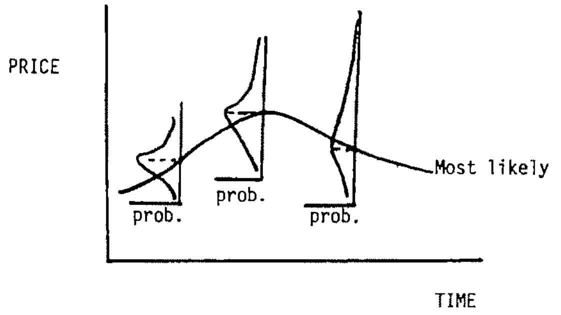


Figure 1.

laying them on the expected prices in the future, the probability and size of possible price increases or decreases after a "forward" purchase can be approximated and incorporated into a rational management decision process. Additional factors critical to the management decision on the commodity price level at which a forward price ought to be made include the expected price of the product to be sold by the firm, the resulting margin, expectations regarding competitor's behavior in both the commodity and product markets (e.g., their cost levels, product pricing and advertising behavior, and the potential sales and market share of each competing firm), and the level of risk acceptable to firm management. These will be considered briefly in the following sections.

Product Market Structure: Commodity Contribution to Product Cost

As the contribution of a commodity to variable manufacturing costs increases, its potential influence on wholesale and retail product prices also increases. As a consequence, mistakes in procuring the commodities contributing a high percentage of product cost can result in greater competitive disadvantages or adverse consumer reactions.

In contrast, commodities which have little influence on product costs if their prices change significantly are less likely to warrant risk taking or management time, because payoffs are greater elsewhere. As a consequence, one would expect the primary management motivation to achieve planned cost levels and avoid surprises regarding minor commodity costs, resulting in a forward commodity purchase even when there may be a fairly high probability of lower prices in the future, and small chance of higher prices. If the minor commodity is a necessary part of the production process, has little or no substitution possibilities, and there is some uncertainty regarding the dependability of supply sources, security of supply would be expected to be considered more important than price. Thus, we would postulate that the probability threshold or trigger point at which the commodity price would be fixed for minor commodities would be higher than for comparable "major" commodity inputs; a lower probability of a competitor achieving a lower price would be generally acceptable for "major" commodity inputs, because there typically is a much larger potential loss associated with a "major" commodity competitive disadvantage.

Product Differentiation and Market Share

The demand curve for a food-manufacturing firm's product reflects (*a*) the industry demand curve for the product in the relevant market (reflecting degree of product differentiation or substitutability), and (*b*) the influence of rivals' behavior in pricing, advertising, and promotion. While specification of the relative strength of these factors is a formidable task (Scherer, p. 149), the firm's evaluation of the potential advantages and disadvantages of alternative commodity procurement strategies would be influenced strongly by their relative importance.

Let us first consider a firm with a strongly differentiated product or a very large market share. A small rival who gains a short-term cost advantage may have difficulty in significantly expanding sales from current retail space, or gaining retail shelf space in stores where they previously have not been represented, even if the small firm utilizes the cost advantage to increase advertising and promotion or maintain a lower product price than its large rival. In a similar vein, firms faced with few small competitors with little excess production capacity or in an industry with high barriers to entry would have little concern that their comparatively high commodity costs and product prices might be exploited quickly and dramatically by competitors. On the other hand, large, well-financed competitors with significant excess production capacity might be more likely to exploit any competitive advantage as quickly and decisively as possible; typically, though, the cross-elasticity of demand for the dominant firm or the firm with a strongly differentiated product, especially in the short run, may appear sufficiently small that the sales impact of movements along the firm's demand curve would be the primary management concern.

The marketing manager of a dominant firm with a differentiated product, though still with an elastic demand curve in the short run, would be expected to be concerned primarily with the potential sales losses incurred if commodity cost increases forced retail price increases, especially if the product were a frequently purchased item and the unit retail price moved up into a particularly elastic segment of the demand curve (like into the next decile, the next dollar level, or a level that would trigger significant media attention as occurred during some periods of rapid food price inflation in the mid-70s). While the market power of the firm might allow it to pass increased costs on to the consumer, the effect of a

price increase on a firm's unit sales and market share, though relatively small, may be sufficiently large to prompt marketing managers rewarded on the basis of sales and market share generally to recommend procurement strategies which would minimize the risk of increased commodity costs. Correspondingly, firms with strong brand franchises or dominant market shares would be expected to be more likely to establish their commodity costs in advance of use, and at price levels where the probability of significantly lower costs was still high (perhaps higher than 50%) to eliminate the risk, though small, of significant commodity cost and product price increases. Following that strategy, the firm would be more likely to avoid jeopardizing the achievement of their short-run profit plans.

Food-manufacturing firms operating in product markets characterized by slight product differentiation would be expected to be acutely conscious of the behavior of rivals in the product and commodity markets (Scherer, p. 131). Unless the rivals had little excess capacity, or could not exploit a competitive advantage for some other reason (perhaps a dominant position of its competitor), one would expect the firm's commodity procurement strategy to be based primarily upon expectations regarding commodity price movements and those elements of rivals' commodity and product market strategies which would significantly influence the position and shape of the firm's demand curve (and the corresponding commodity demand).

Most firms dealing in weakly differentiated products would be expected to follow the same procurement strategy as their primary rivals to avoid the risks of significant competitive disadvantages. Procurement strategies would be avoided which might lead to significant losses on commodity inventories, through forcing product prices higher than competitors', or through a reduced value of inventory (sometimes required to be reported in quarterly financial statements). In most firms, this would be evident through "forward" pricing of commodities only if forward product sales had been made, general avoidance of forward purchases, or policies of hedging commodity inventories if forward commodity purchases were required to insure adequate supply. Exceptions would be anticipated if (*a*) competitors were expected to make forward purchases, and matching that strategy reduced the chance of a significant competitive disadvantage; or (*b*) if commodity prices could not drop significantly lower, perhaps due to the influence of government price support programs, making a competitive disadvantage resulting from a forward purchasing mistake highly unlikely.

The Rivalry Process in Imperfect Markets

How might a firm exploit a competitive advantage in raw material cost? If the advantage is small for a short period of time, it may not be sufficient to offer a significantly lower retail price, to significantly increase the firm's advertising and promotion, or to enter a new market area. However, the cost advantage required to initiate such efforts successfully is clearly greater in markets involving sharply differentiated products. Thus, the probability is much greater that a significant competitive advantage could be gained by firms dealing in less differentiated products and volatile input (commodity) markets. Because the relative impact of a unit change in relative price or advertising and promotion expenditures on the firm's undifferentiated product sales would be expected to be large, managers would attempt to minimize the risk of a competitive cost disadvantage in that structural environment.

A rival may choose to let a cost advantage filter down to the "bottom line" in the form of increased profits, particularly if other costs are rising rapidly or other parts of the business are not faring well. However, a firm may elect to exploit a cost advantage via lowering prices or increasing advertising and promotion, hoping to expand market share and enhance long-term growth and profit prospects. The firm's choice of strategies regarding price or discretionary expenditures would depend upon its evaluation of (*a*) the likelihood of competitors meeting its price, (*b*) the consumer response to the price, (*c*) the likelihood of competitors matching the firm's changed advertising and promotion expenditures, and (*d*) the consumer response to the firm's advertising and promotion, where the consumer response (*b* and *d*) would be contingent upon the extent to which rivals match the firm's actions (*a* and *c*). Some possible choices of strategy are illustrated in figure 2.

How might a firm combat a rival who has a short-term, but significant, cost advantage? If the rival elects to increase short-term profits, little effect will be felt and no reaction may be required. If, however, the rival elects a lower price, the firm can maintain its higher price and take its consequences in reduced current (and probably future) sales. Alternately, the firm could meet the lower price and reduce its profit margin or its spending on such discretionary activities as advertising, promotion, and new product development. A reduced profit margin would hurt primarily in the current period, while reduced new product development or research spending primarily would hurt firm growth and profitability in subsequent time periods. Reduced advertising and promotion, in contrast, would affect sales and profitability currently—and in the future if lost customers are difficult to win back. The firm's evaluation of the costs or benefits associated with procurement strategy mistakes or successes in their competitive environment would be a critical influence in determining the optimum procurement strategy guidelines for individual product lines within the firm.

Market price trend after forward purchase	Procurement Strategy: Forward Purchase	Procurement Strategy: Purchase at Time of Use
Increase	Exploit advantage by: (1) maintain product price, increase market share. (2) increase price, increase advertising, and promotion, market share. (3) increase price and profit margin.	Minimize disadvantage by: (1) increase price, and hope competitors follow. (2) increase advertising, couponing, to minimize sales decline at a higher price. (3) match competitors prices, maintain sales, but accept lower margin. (4) maintain prices, and cut discretionary expenditures to minimize short-run profit decline.
Decrease	Minimize disadvantage by: (1) meet rival's lower price, maintain sales, but accept lower margins. (2) maintain price, but increase promotion to counter sales losses. (3) maintain price, accepting reduced sales and share. (4) meet lower price, and cut discretionary expenditures to minimize short-run profit decline.	Exploit advantage by: (1) reduce product price, possibly increasing sales and market share. (2) maintain price, and increase discretionary expenditures (R&D, advertising), increasing sales and market share. (3) maintain price, increasing profit margin.

Figure 2. A simplified illustration: some firm responses to commodity cost advantages/disadvantages

Influence of Business Objectives

At different stages of a product or business life cycle, the priorities among alternative management objectives might be quite different, leading to different choices of commodity procurement strategies. Within many multiproduct corporations, individual lines of business are classified according to their future growth and profit potential, with management objectives and strategies tailored accordingly.[1]

(*a*) Very low growth and profit potential: new investment and discretionary expenditures on advertising and research are minimized, except as required to extract the maximum cash flow from previous investment. Cost reduction is a primary goal, perhaps even to the extreme of a small sacrifice of product quality.

(*b*) Very high growth and future profit potential: funds for plant and equipment, research and new product development, and advertising and promotion are channeled into these businesses, with the objectives being maximum sales growth, satisfactory current returns, and little concern regarding a negative cash flow.

(*c*) Slow growth, but still good profit potential: usually an established business; funds would be channeled into the business to maintain the slow growth and established profit contribution, but

[1] In the food industry, Heinz and Standard Brands are two examples cited in the literature (see references) who use this fairly common approach. Many others use similar approaches, following procedures similar to those developed by General Electric or some prominent management-consulting firms.

some funds generated would be allocated to the high growth potential enterprises.

In products where sales and market-share growth are primary short-term objectives to enhance ultimate long-term profitability, managers would be expected to be quite reluctant to adopt a strategy having even a slight risk of a rival gaining a short-term competitive advantage. Market share losses would be considered anathema by top management. In contrast, managers of businesses where short-term profits and increased cash flow are highest priority would be expected to be more flexible and willing to accept a moderate risk of competitive disadvantage, especially if the potential cost advantage from the procurement strategy are sufficiently large and probable in the manager's view. However, the size and probability of the potential competitive disadvantage generally would have to be within "tolerable" limits, or the strategy which otherwise would seem to be an attractive option would not be selected. Such risk-management behavior seems consistent with the usual structure of management reward systems in food-manufacturing firms; these typically are asymmetric, providing moderately positive rewards for extraordinarily good results, but reductions in a manager's promotion potential or even loss of a job if negative results occur occasionally, even though the risk taken might seem reasonable a priori.

Other Internal Firm Considerations

The firm's commodity procurement strategy will often reflect its financial strength and degree of product (and commodity) diversification. While well-financed firms may be more flexible in their procurement strategy because of their ability to weather any short-term competitive disadvantage, firms in a weak financial position may be forced to strategies minimizing the chance of any competitive disadvantage. In some situations, a highly probable, low commodity-cost opportunity may have to be foregone because of the firm's inability to withstand the adversities associated with being wrong, even though it was a very low probability event.

While managers of single product businesses would tend to minimize the risk of the most discomforting results in their product and key commodities, even when the odds of favorable consequences might be reasonably high, multiproduct firm managers would tend to accept greater risk of adversity in individual products or commodities. The consequences of loss in one product or commodity would be proportionately less in the diversified business, and the odds favoring positive results in many individual strategies generally would lead to favorable results outweighing losses. Such differences in behavior require that the overall corporate risk-management objectives are communicated clearly to managers of individual product businesses within the diversified corporation, and that risk-management guidelines are adjusted from the single-product management objectives that the middle manager otherwise would be expected to have.

Available Evidence

Commodity procurement strategies and results in most food-manufacturing firms typically are closely held within the firm because of the potential competitive repercussions. As a consequence, available evidence is not extensive, and frequently must be camouflaged to avoid disclosure of individual firm behavior.

There have been a few published case studies of firm-procurement behavior in imperfect markets. Arthur (Part III) cites several examples of firms dealing in undifferentiated products (wheat flour, industrial chocolate, soybean oil, fresh meat) where the price of key commodities typically is not established until immediately prior to use unless advance fixed-price product sales have been made. In contrast, Arthur cites several examples of "proprietary grocery items" (i.e., differentiated consumer products) where the firm's procurement policy allows commodity costs to be established prior to the time of use. Some of the products cited in this category include chocolate chips, other cocoa-based products, candy, and orange juice.

Managers in more than a dozen large food-manufacturing firms, and specialized commodity consultants dealing with another twenty to thirty food-manufacturing firms, were interviewed on a "not-for-attribution basis." The observations of those interviewed (and the author's experience in a diversified food-manufacturing firm) were generally consistent with the postulated behavioral relationships discussed earlier. Some case examples cited by those interviewed are discussed below.

Managers producing slightly differentiated products (vegetable oils and margarine, industrial flour, packaged grocery flour, industrial and retail sugar, industrial chocolate, a wide variety of "private label" products, frozen orange juice, and fresh meat) have a strong tendency to avoid exposure to a competitive disadvantage related to commodity procurement mistakes. Inventories are typically heged where possible, kept to a minimum, or kept on a par with competitors to reduce the risk of a significant competitive disadvantage. Open forward positions occasionally will be taken, but only when a significant profit potential is quite probable and the probability of commodity prices dropping is quite low.

Manufacturers of refined beet sugar and frozen orange juice are two examples where their commodity-procurement risk is minimized through the use of contracts (called participation plans in the citrus industry) under which the price paid to the supplier is based on the selling price of the

manufactured product, shifting most of the price risk from the manufacturer. Vegetable canners and freezers are an interesting contrast, in that forward purchases via production (acreage) contracts apparently are essential to insure adequate supply and quality, but fixed price sales or "hedging" of the contractual commitment typically are not feasible (in contrast to commodities like flour, cocoa, and sugar); while production is contracted for well in advance of sales, most contracts are negotiated at approximately the same time, with careful attention to competitors' offers to acquire adequate supply without exceeding competitors' costs in the relevant producing areas. These and other manufacturers of slightly differentiated products typically follow strategies similar to most feed manufacturers and grain merchandisers, avoiding price risk or exposure in commodity markets when sales or selling prices of their product are quite responsive to actions of competitors. The responsiveness of sales to even small differences in price is so intense that any cost disadvantages are virtually certain to be directly and fully reflected in reduced firm profits, unless there is insufficient capacity among competitors to satisfy consumer requirements.

Business managers with strongly differentiated products (e.g., specialty breads, candy and confectionery products, snack foods, cake mixes, cookies, cereals, canned and soft moist dog foods) or dominant market shares have a strong tendency to take "forward" positions in their minor commodity inputs and avoid the risk of higher costs, even when their forecasts may suggest a reasonably high probability (e.g., 50%–65%) of slightly lower costs, and a 20%–25% probability of significantly lower costs in the future, especially if purchase prices are within the parameters of their financial plan for that business segment. The tendency is nearly as strong for primary commodities used in those products to be purchased in advance, though the acceptable probability of significantly lower costs is typically lower (e.g., 10%–15%) than for minor commodities in the same business (e.g., soybean meal vs. sugar in dog food). There clearly is a strong tendency for the manufacturers of strongly differentiated food products or with strong market positions to buy in advance and "lock up" a planned margin, thus avoiding a product price increase when there is an opportunity to do so.

Summary and Conclusions

In contrast to industries facing supply firms with administered pricing systems, the volatility of commodity (input) prices in the food-manufacturing sector may result in more unsettled competitive relationships among firms than in otherwise comparable manufacturing industries; it seems likely that shifts in the "low cost producer" position resulting from commodity procurement successes or mistakes relative to competitors make joint profit maximization behavior less likely to be attempted or to succeed in oligopolistic market structures in the food industry. There probably would be more opportunities for the potential "maverick" to find himself in a position where price cutting or additional advertising could be afforded due to a commodity cost advantage, putting rivals in an awkward competitive position and enhancing his own position.

What are the implications for effective purchasing-management systems? Clearly, there is a strong interrelationship between a firm's product market and commodity market risks. As a consequence, having the commodity procurement function managed as a separate profit center or commodity purchase decisions made without considering relevant product market risks could jeopardize the viability of the firm or business unit. In a stable commodity market environment, procurement mistakes seldom could be large. The increased commodity market volatility observed in recent years makes essential the effective integration of commodity market and product market risk management in most food-processing and -manufacturing firms. As the magnitude of potential gains or losses from alternate procurement and marketing strategies, and the complexity of the management task increase, the talent and resources required for effective management have clearly escalated.

In conclusion, this is a complicated risk management problem—one that is not unique to the food industry, but one which most economists and many managers have not analyzed comprehensively even though this element of risk management in the food industry has become much more important in the recent volatile commodity-market environment. Food-manufacturing firms dealing in imperfect product market structures and uncertain and volatile commodity (input) markets have a complex, multifaceted management decision process where maximum profit, at least in the short run, is clearly not the sole decision criterion, even for those firms dealing in product markets characterized by little product differentiation or concentration of market power. Thus, we see that it might be quite rational for firms to take different actions in volatile commodity markets, leading to corresponding differences in firm and industry behavior and performance. While realistic deterministic models of firm behavior in such imperfect market settings may not be feasible, exploring the behavior of firms dealing with varying degrees of product market and input market risks appears to be a fruitful area of research which can be instrumental in improving our understanding of behavior and performance in the entire food-marketing and distribution system.

[*Received April 1978; revision accepted October 1978.*]

References

Arthur, Henry B. *Commodity Futures As a Business Management Tool.* Boston: Harvard Business School, Division of Research, 1971.

"How H. J. Heinz Manages its Financial Planning and Controls." New York: American Management Association Financial Mgmt. Series No. 196, 1953.

Kaysen, Carl. "The Corporation: How Much Power? What Scope?" *The Corporation in Modern Society,* ed. E. S. Mason, Cambridge, Mass.: Harvard University Press, 1960.

Scherer, F. M. *Industrial Market Structure and Economic Performance.* Chicago: Rand McNally & Co., 1970.

"Standard Brands: A Blueprint for a New Packaged Goods Drive." *Business Week,* 6 Feb. 1978, pp. 90–93.

Domestic Food Programs and Their Related Impacts on Retail Food Prices

Mike Belongia

In 1977 over $7 billion in federal outlays were distributed through domestic food assistance programs. Because our food supply is relatively fixed in the short run, any demand expansion generated by the supplemental income of food assistance programs should exert some upward pressures on retail food prices. Assuming that federal food assistance programs do add positive increments to total food expenditures and that the increase in expenditures will have some positive impact on food prices, the question becomes one of quantifying the magnitude of the price increase.

This paper links the findings of two independent studies which investigated this question. Schrimper constructs a theoretical model useful in placing bounds on retail price impacts under alternative assumptions about market conditions. Belongia and Boehm, in contrast, estimate four statistical models to isolate and quantify the variable price impacts of bonus food stamps on the consumer price indexes (CPI) for all food and major food groups. Although Belongia and Boehm deal only with the Food Stamp Program (FSP) while Schrimper considers four food assistance programs, FSP is clearly the focus for the analysis. Because FSP represents over 60% of U.S. Department of Agriculture (USDA) outlays for food assistance, its impact on retail prices can be considered an upper bound on the effect that any single program may have on food prices. Finally this summary report also can provide guidelines for evaluating the effect of the elimination of the purchase requirement (EPR) and other welfare reforms. As restrictions on food assistance income are made less rigorous, the programs can be expected to generate smaller increases in food expenditures and thus have smaller impacts on food prices. The authors of both studies conclude that through 1977, U.S. food assistance programs have had a positive but very small impact on the retail price of food. Their results are compared and discussed here, followed by an interpretation of the findings in reference to EPR and welfare reform in general.

Mike Belongia is an economist with Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture.

Ron Schrimper is gratefully acknowledged for granting his permission to cite extensively from his work. Thomas A. Stucker, William T. Boehm, Richard A. King, and anonymous *Journal* reviewers are also acknowledged for their helpful comments on drafts of this paper. The author is solely responsible for any remaining errors. The views expressed do not necessarily reflect those of the USDA.

Theoretical Considerations

The theoretical aggregate market impact of food assistance dollars is shown in figure 1 as a rightward shift in demand. In the absence of a food income transfer program like the FSP (or at "current" levels of aid), total food expenditures would be ($P_1 * q_1$). A net increase in aid (assuming supply is constant), either because of an increase in program participation or because the real value of the aid per participant is increased, would be expected to increase total food expenditures ($P_2 * q_2$). The net result ($P_2 * q_2$) − ($P_1 * q_1$) is due entirely to increases in the food buying income support.

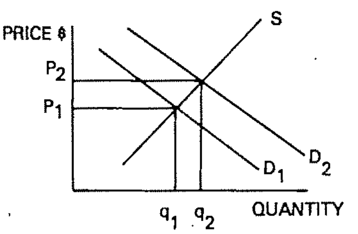


Figure 1. Theoretical shift in food demand associated with food assistance programs

As long as the supply curve is not perfectly elastic, a *ceteris paribus* shift in demand will increase both the price level for the good in question as well as the quantity taken from the market. The extent of the relative price or quantity impact will depend on (*a*) the shift in demand, (*b*) the elasticity of demand, and (*c*) the elasticity of supply. The income elasticity for all food relative to that for individual food commodities would suggest variable price impacts. That is, in a program through which purchases are made at the discretion of aid recipients, some goods will be favored over others.

The Schrimper Study

Schrimper, using such guidelines, analyzes the probable price impacts of four USDA food-aid programs.[1] To conduct the analysis, he examines the

[1] The programs are the Food Stamp Program (FSP), Child Nutrition, Food Distribution, and WIC.

factors that should affect the retail price of food. He begins with the market clearing-price formulation:

$$(1) \qquad EP_r = (n - e)^{-1} EQ_r,$$

where EP_r is the percentage change in the retail price of food; EQ_r is the percentage change in total demand for food at the retail level induced by government food programs; n is the price elasticity of the retail supply of food; and e is the price elasticity of the retail demand for food.

Under these considerations, a final retail food price increase could be the result of the interaction of several factors. At first glance EQ_r appears to be the term of primary importance as any positive change in total retail demand, via the food programs, *ceteris paribus*, will generate a positive percentage change in retail prices. However, it is also evident from equation (1) that the final percentage change in retail prices will be produced directly by the price multiplier, $(n - e)^{-1}$, associated with any change in retail demand affected by the food programs. To account for all possible combinations of impacts on retail prices, both the demand expansion term and the price multiplier must be dissected to discern what factors influence their magnitudes.

Elasticity-Based Changes

Because of the biological nature of food products, they cannot be produced instantaneously to meet the needs expressed by an increased market demand. Thus, the existence of a perfectly elastic supply curve can be discounted. As such, the expression of the price multiplier indicates that if food programs create any net increases in total retail food demand they must exert some upward influence on retail food prices. Knowing the direction of the influence, the question centers around the magnitude of the price impact. As equation (1) also shows, larger elasticities of demand or supply will dampen the magnitude of the price increase.

Finally, equation (1) indicates that length of run will influence the extent of the price impact. Since the elasticities may vary with the length of the adjustment period, it can be reasoned that initial price increases may be larger than the price achieved after a longer adjustment period. But regardless of how short the adjustment period, a perfectly inelastic supply does not exist especially when international trade flows are considered.

Demand-Induced Price Changes

The other term of equation (1), the demand expansion term (EQ_r), can be divided into component elements reflecting how retail-level demand for food might be increased. Specifically, the relationship can be expressed:

$$(2) \qquad EQ_r = EB^* \lambda,$$

where λ is the share of the total food market accounted for by food program participants, and EB is the percentage increase in the retail food demand of program participants.

The terms λ and EB show that either increased food program participation or improved program efficiency in increasing the food expenditures of program participants will increase the total retail demand for food.

Demand Expansion by Participants

The problem of "slippage" is encountered when trying to derive estimates of EB; that is, not every dollar allocated from food assistance programs is spent on food. Particularly in the case of bonus stamps, there are indications that bonus stamps tend to replace other types of disposable income for food expenditures thus "freeing" this income for additional food or nonfood expenditures. For instance, other studies have placed the food-buying effectiveness of bonus stamps between 40¢ and 55¢ per bonus dollar (Reese, Feaster, Perkins; Southworth). This level of effectiveness is expected to be significantly lower, maybe half its current figure, after the implementation of EPR in early 1979. So the demand expansion term is dependent upon the extent to which food aid dollars merely replace private food expenditure dollars. That is, although bonus issuance may have a value of $5 billion, one half that amount is allocated to food expenditures while the remainder serves as a replacement to earned income now freed for nonfood purchases. Evaluation of changes in net food demand is then dependent on an estimate of change in demand rather than the proportion of bonus stamps used for increasing food purchases.

Conclusion of Schrimper Study

Table 1 summarizes the expected percentage change in retail food prices for each 10% increase in food demand by program participants, given the reasonable range of values for λ and EB which are derived in the text of Schrimper's paper. He explains that although the values in the table are proportionally related to each other, they can be used to represent bounds on price effects for each 10% increment in the food demand of program participants under alternative assumptions about their share of the food market. Depending, then, upon the elasticity of the retail supply of food and the market share of participants, each 10% increase in participant demand could result in retail food price increases from .08% to 4.0%.[2] This range of potential price increases is narrowed by assuming an elasticity of supply equal to 0.8 or larger. Thus, Schrimper concludes that an increase in participant

---

[2] Using equation (1), $EP_r = [0 - (-.2)]^{-1} * .08 * 10 = 4.00$; $EP_r = [5 - (-.2)]^{-1} * .04 * 10 = .08$. A price elasticity of retail demand equal to $-.2$ is assumed.

Table 1. Results of the Schrimper Study: Percentage Change in Retail Food Price for Each 10% Increase in Demand by Program Participants under Alternative Conditions

Alternative Price Elasticity of Retail Supply of Food	Participants' Share of Food Market	
	.04	.08
0.0	2.00	4.00
0.3	.80	1.60
0.8	.40	.80
1.5	.24	.47
3.0	.13	.25
5.0	.08	.17

Note: Calculations based on equation (1) assuming price elasticity of retail demand for food is −.2.

food demand of 30% to 50%, assuming supply elasticities between 0.8 and 5.0 would effect changes in retail food prices between .24% and 4.0%. It appears, then, that only under the most rigid assumptions about an inelastic food supply and only for relatively large increases in the food demand of participants could food programs be responsible for a significant share of the 60% increase in retail food prices between 1970 and 1976.

The Belongia-Boehm Study

Also working from the basic theoretical approach of figure 1, Boehm and Belongia set out to quantify more closely the ranges of price impacts suggested by Schrimper's theoretical model. As that analysis suggests, concentration on the basic shifters of the demand for and supply of food and food products in major commodity groups is key to the estimation. Models to reflect these relationships were developed and estimated by ordinary least squares regression. Quarterly data from 1970:1 through 1977:2 were used in the estimation.

These models and the results of the estimation are reported in table 2. Mean values for the vari-

Table 2. Statistical Models and Results of the Belongia-Boehm Study

Explanatory[a] Variable	Consumer Price Index: All Food	Meat, Fish, Poultry	Cereals Bakery	Dairy
Constant	1.53	−113.69	92.75	−4.237
Y	.027	.351	−.084	.074
	(1.04)	(6.00)	(−2.10)	(1.76)
B	3.046	14.695	14.825	4.647
	(2.13)	(4.09)	(6.00)	(1.71)
L_{-1}		−.013		
		(−4.80)		
G_{-1}		−.024	.029	
		(−.86)	(1.49)	
M_{-1}	.489	−.077	.565	.408
	(8.82)	(−.48)	(5.25)	(3.36)
D				−.001
				(−1.21)
DS				.001
				(2.61)
Z	−2.834	−4.728	−4.422	−3.920
	(−2.12)	(−1.37)	(−1.79)	(−1.46)
R			14.822	
			(7.13)	
FP_{-1}	.250			
	(7.46)			
R^2	0.99	0.96	.99	.96
DW	1.63	2.12	2.22	1.05
F	751.34	78.64	253.78	95.77

Note: The period of estimation included 30 quarterly observations from 1970:1 through 1977:2.

Variable definitions: CPI_t is the consumer price index for the relevant food commodity in quarter t, as reported by the U.S. Department of Commerce, 1967 = 100; FP_{t-1}, an index of prices received by farmers for their produce in quarter $t-1$, 1967 = 100; Y_t, disposable per capita personal income in quarter t in 1967 dollars; B_t, per capita Food Stamp bonus in quarter t in 1967 dollars; L_{t-1}, U.S. total meat production in quarter $t-1$, in millions of pounds; G_{t-1}, quantity of all grain stocks in the previous quarter $t-1$ in millions of short tons; M_{t-1}, an index of food processing and marketing costs in quarter $t-1$, 1967 = 100; D_t, quantity of milk, in millions of pounds, produced in quarter t; DS_t, dairy stocks in millions of pounds; Z, a zero-one variable indicating the quarters when national price controls were in effect; and R, a zero-one variable to account for the Russian grain sales in 1973–74.

[a] Values in parentheses are t ratios.

ables are found in table 3. The variables in each of the models explained a statistically significant proportion of the variability in each dependent variable vector. The R^2 for the all-food model was 0.99. As table 2 shows, the estimated parameter for bonus (B_t) is significantly different from zero at the .05% level in all but the dairy model. Also, as expected, the coefficient has a positive sign in all models. That is, in each instance, the demand expansion associated with bonus issuance exerted upward pressures on food prices as measured by the CPI. Attempts to correct the serial correlation problem in equation (4), dairy, were made but did not alleviate the problem.

Using the coefficient estimates generated for the bonus variable (B_t) in each of the four regression equations, the effect of a given change in the amount of the bonus on the level of a particular CPI can be determined. The CPI for the all food model resulted in a coefficient estimate for bonus of 3.046. Calculated at the mean, a 1% increase in real, per capita bonus ($.0329) multiplied by this parameter will increase the CPI for food by .1 points. This change can also be expressed as a change of .07% based on the mean value of the CPI for food. A 1% increase in current dollar bonus would be approximately $12.5 million per quarter. Based on current values for bonus issuance, this change would be an increase of $8.84 million expressed in 1967 dollars.

The different parameter estimates for bonus in each of the equations also verify the earlier contention that differences in income elasticities would affect variable price impacts across commodities. The coefficient estimates indicate the largest price impacts would be in the cereal and bakery products and meats groups (.34% and .32%). The magnitude of the impact on meat prices conflicts with Blakely who suggested a much larger increase (5.7%) in beef prices due to bonus food stamps in a 1970–73 period of study. His use of aggregate price elasticities and a one-time injection of $3 billion in food stamps most likely explain the large difference in the estimates. The fact that bonus was nonsignificant in the dairy model also indicates a behavior pattern of food stamp households. Because consumption of dairy products is typically low among black households (Boehm) and a relatively large proportion of poor families are black, little price effect on dairy products would be expected.

Conclusions

A comparison of the price impacts of federal food aid programs reported by the two studies shows the consistency of the two estimates. Using the "most reasonable" of Schrimper's estimates in table 1 where the market share of participants is placed at 4%, with supply elasticities of .4 to 3.0, the estimated change in retail food prices falls between .4% and .13%. As already mentioned, Belongia and Boehm estimate the price change to be a .07% increase in the CPI for all food for a 1% increase in bonus. These estimated price impacts are especially interesting in light of EPR and other welfare reform issues. As the legislation puts fewer restrictions on the use of food assistance dollars, the expansion in food demand resulting from federal aid can be expected to diminish. And because the retail price impact of food assistance programs is related directly to the increase in food demand, such welfare reforms can be expected to decrease the already small impact of food assistance dollars on the retail price of food. Thus, while the two studies reported here suggest positive but very small impacts on retail food prices as a result of food assistance programs, the magnitude of that impact can be expected to decline in the future as restrictions on the use of food aid dollars are relaxed.

[*Received June 1978; revision accepted November 1978.*]

References

Belongia, Mike, and William T. Boehm. *The Food Stamp Program and Its Impact on the Price of Food.* USDA Tech. Rep., in press.

Table 3. Means and Standard Deviations of Variables Included in the Models; All Figures Are Based on Quarterly Values from 1970:1 through 1977:2

Variable Name	Units	Mean	Standard Deviation
CPI, all food	Index 1967 = 100	148.13	27.74
CPI, meat, poultry and fish	Index 1967 = 100	150.78	27.07
CPI, cereals and bakery	Index 1967 = 100	144.96	32.48
CPI, dairy	Index 1967 = 100	138.13	23.26
Y_t	1967 dollars	995.21	43.31
B_t	1967 dollars	3.29	1.10
L_{t-1}	Million pounds	9,366.30	530.79
G_{t-1}	Millions of short tons	94.91	45.52
D_t	Million pounds	29,449.71	1,858.62
DS_t	Million pounds	14,547.00	3,446.00
FP_{t-1}	Index 1967 = 100	157.33	33.30
M_{t-1}	Index 1967 = 100	148.55	30.68

Blakely, Leo V. "Domestic Food Costs." *Amer. J. Agr. Econ.* 56(1974):1103–12.

Boehm, William T. "The Household Demand for Major Dairy Products in the Southern Region." *S. J. Agr. Econ.* 7(1975):189–96.

Reese, Robert B., J. Gerald Feaster, and Gary Perkins. *Bonus Food Stamps and Cash Income Supplements: Their Effectiveness in Expanding the Demand for Food.* USDA ERS Mktg. Res. Rep. No. 1034, Oct. 1974.

Schrimper, Ron. "Food Programs and the Retail Price of Food." *Agricultural Food Policy Review II.* USDA ESCS-AFPR-II, Sept. 1978.

Southworth, Herman M. "The Economics of Public Measures to Subsidize Food Consumption." *J. Farm Econ.* 27(1945):38–66.

U.S. Department of Agriculture. "Dietary Levels of Households in the United States." *Household Food Consumption Survey, 1965–66.* Agr. Res. Serv. Rep. No. 6, Spring 1965.

Farm Planning and Calf Marketing Strategies for Risk Management: An Application of Linear Programming and Statistical Decision Theory

Tesfaye Gebremeskel and C. Richard Shumway

Budgeting and linear programming (LP) techniques frequently have been used to evaluate the profitability of alternative management strategies for cow-calf producers. However, two deficiencies are apparent in much of this literature. Although it is generally acknowledged that producers are concerned about riskiness as well as profit potential of alternatives, relatively little attention has been given to forage and cattle management strategies to reduce risk. Forage quality also typically has been ignored. This oversight often results in technically infeasible solutions because the animal cannot eat enough to obtain the necessary nutrients (Whitson, Parks, Herd).

Objectives

This study addresses both of the above problems for a cow-calf producer on the Texas Gulf Coast. A risk constrained linear programming model is adapted to handle intermediate and final products (i.e., forages and beef). The model accounts for forage quality and is used to determine forage species, fertilization rates, herd size, and degree of on-farm integration for solutions on an expected net return-mean absolute deviation *(E-A)* efficient set. The effect of calving season on the risk-constrained solutions is also evaluated. By integrating statistical decision theory with the LP model, annual calf-marketing strategies are derived based on observable information relevant for predicting subsequent calf prices and forage yields. The impact of the annual strategies on the *E-A* efficient set is then examined.

Tesfaye Gebremeskel, former research assistant at Texas A&M University, is an assistant professor in the School of Business, Texas Southern University. C. Richard Shumway is an associate professor in the Department of Agricultural Economics, Texas A&M University.

Technical Article 13889 of the Texas Agricultural Experiment Station.

The authors wish to thank Marvin Riewe, Neal Pratt, Tom Cartwright, Charles Long, Hovav Talpaz, Robert Whitson, Peter Barry, Enrique Ospina, and Dennis Henderson for providing data, making constructive suggestions, or otherwise assisting with this study.

Method of Analysis

Quadratic programming (QP) codes are used most commonly to analyze alternatives in which both expected profit and risk are important dimensions (e.g., Whitson, Barry, Lacewell). QP permits tracing out efficient sets of solutions that minimize variance in profits at alternative expected profit levels. Hazell and Scandizzo have demonstrated that LP can be used to approximate QP solutions if risks are defined using absolute deviations rather than variance. It is unlikely that individual producers are so precise in their evaluations of risk that they discern levels of riskiness measured in terms of variance from those measured in absolute deviations. Because other basic assumptions of the two models are comparable, there is no conceptual preference for (QP). An LP code is selected for use in this study because of computational cost advantages.

Farm Planning (Long-Run Decisions)

Hazell's "minimization of total absolute deviations" (MOTAD) LP model has been used to evaluate expected profit-risk tradeoffs in crop production where historical risks are due to variability in yields and/or factor and product prices. This model is adapted here for a production process including intermediate and final products.

Most forage required by a Texas cow-calf operation is produced on the farm and grazed rather than being purchased. Consequently, historical data on forage prices are inadequate to determine gross return deviations for pasture activities. A modified MOTAD model is proposed that handles this problem by measuring forage yield deviations in two-month periods and by permitting purchase or sale of hay in order to produce a constant quantity of beef each year. It is specified in the form of maximizing expected net returns subject to parametric restrictions on mean absolute deviations in net returns. This is equivalent to Hazell's specification which minimizes total absolute deviations subject to parametric restrictions on expected net returns.

Major aspects of the adapted model are illustrated in table 1. This example considers two forage sources, two seasons, two forage qualities, supplementation of low quality forage, two beef-marketing alternatives, and two years of data. Fea-

Table 1. MOTAD Model Example for Beef Production

		Forage (Acres)		Supplement (Mcal.)		Beef Activity (No.)		Hay Sale (Tons)				Hay Purchase (Tons)				Annual Deviations ($)				
								Year 1		Year 2		Year 1		Year 2		Positive		Negative		Constraint
		Bermuda-grass	Rye-Ryegrass	Season 1	Season 2	Cow-Calf	Stocker	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Year 1	Year 2	Year 1	Year 2	
Row	Unit	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	
1. Expected net returns	Dollars	−69	−97	−.05	−.05	191	64	15	15	13	13	−30	−30	−27	−27			−.0001	−.0001	Maximize
2. Land restraint	Acres	1	1																	≤ 500
3. Mean forage production and consumption:																				
a. High quality, season 1	Mcal. DE[a]	2,800		2.3			−1,200													≥ 0
b. High quality, season 2	Mcal. DE	1,900	6,500		2.3	−1,800	−1,200													≥ 0
c. Low quality, season 1	Mcal. DE	4,100		−1		−6,000														≥ 0
d. Low quality, season 2	Mcal. DE	300			−1	−3,200														≥ 0
4. Deviations in forage production:																				
a. Year 1, season 1	Mcal. DE	−2,700	−300					−2,000				1,900								= 0
b. Year 1, season 2	Mcal. DE	4,500	−700						−2,000				1,900							= 0
c. Year 2, season 1	Mcal. DE	2,700	300							−2,000				1,900						= 0
d. Year 2, season 2	Mcal. DE	−4,500	700								−2,000				1,900					= 0
5. Deviations in net returns:																				
a. Year 1	Dollars			−.015	−.015	−43	−17	15	15	−13	−13	−30	−30	27	27	−1		1		= 0
b. Year 2	Dollars			.015	.015	43	17	−15	−15	13	13	30	30	−27	−27		−1		1	= 0
6. Annual mean absolute deviations in net returns	Dollars															.5	.5	.5	.5	≤30,000

[a] Megacalories of digestible energy.

tures of the model not illustrated in the table include activities for (*a*) harvesting excess forage in one season for later feeding, (*b*) using high quality forage to meet low quality consumption requirements, and (*c*) transferring calves from one production phase to either the next production phase or to market (e.g., from cow-calf to either stocker production or to weaned calf sale).[1]

The conventional LP profit-maximizing model for this problem has the same objective function but is subject only to resource and forage production-consumption constraints (e.g., rows 2, 3a, 3b). In most studies row 3 is not differentiated into quality categories. Hazell's MOTAD crop model adds row 4 measured in annual net return (i.e., gross return net of variable cost) deviations, and a matrix to transfer annual deviation sums to a constrained total absolute deviation row. The remaining portions of table 1 are necessary to accommodate the intermediate product, its seasonality of production, and different prices associated with positive and negative yield deviations.

Because forage production and animal consumption requirements vary substantially among seasons, expected forage supplies and requirements are specified by season (row 3). Expected deficits in any period must be met by feeding hay produced earlier. Except for concentrate supplements required during the finishing phase and in certain cases when low quality forage is fed (columns 3 and 4), the model is structured so that all feed required by the beef herd in the mean year is produced on the farm.

Forage quality (i.e., nutrients per unit dry matter) also varies substantially among seasons. As the quality of forage decreases, digestibility decreases and the animal's voluntary intake of that forage also decreases (Conrad, Hibbs, Pratt). It is possible, therefore, for an animal to eat all the forage it will and yet not satisfy either energy or protein requirements to achieve the desired growth rate (Whitson, Parks, Herd). This problem is addressed by (*a*) determining the minimum quality of forage necessary each season to meet the animal's nutrient requirements without exceeding its voluntary intake capacity and (*b*) supplementing low quality forages with concentrates as needed at least to satisfy minimum digestible energy and protein requirements. A high quality forage category is defined to include only those forages that meet the minimum quality requirements of all cattle (cow, calf, stocker, and yearling). In the actual model, row 3 is composed of 12 rows, high and low quality forage production in each of six bimonthly seasons.[2]

Forage yield variability between years is largely responsible for beef production variability. Historical yield variability is represented as deviations from expected seasonal yields (row 4, columns 1–2). Deviations in forage supplies between years are converted into monetary terms through purchase and sale of forage in the form of hay (columns 7–14). Hay may be sold (or purchased) in any season when forage supply exceeds (or is below) that period's mean value. These seasonal deviations in net returns due to forage variability are transferred to row 5 where they are added to annual net return deviations due to historical variability in beef and supplemental feed prices.

Forage purchase and sale prices are not equal because harvesting and transportation costs must be deducted from sale price. Also, because some forage is wasted during harvest, the amount of forage required to produce a ton of hay is greater than the amount available to cattle from that ton. To assure that positive net return deviations are equal to negative deviations (i.e., so that the objective function reflects mean performance), the effect of both purchase and sale actions on expected net returns (row 1) and variability in net returns (row 5) must be considered. Assuming that one ton of hay is available from excess forage production in year 1, season 1 in the example, the expected annual return from that ton is equal to its price (p = \$30) divided by the number of data years (t = 2). That value (\$15) enters objective row 1, column 7. The remainder of the return, $(t - 1)\ p/t$ (or \$15), accrues in the actual sale year (year 1) and enters deviation row 5a, column 7. This leaves a negative deviation in other years equal in magnitude but opposite in sign to expected annual return. Consequently, $-p/t$ (or −\$15) is entered in deviation row 5, column 7 for all other years (i.e., row 5b in the example).

The positive (or negative) sum of all gross return deviations from forage yield, beef and supplemental feed price variability for year 1 is transferred via column 15 (or 17) to annual mean absolute deviations (row 6). The constraint on this row is parametrized from ∞ to 0 to trace out the *E-A* efficient set of long-run farm plans.

Annual Calf Marketing Strategy

In forage and cattle production, many decisions take the form of capital investments and cannot always be modified greatly in the short run. Besides investment in land, buildings, and equipment, other long-term decisions include the selection of perennial forages, herd size and breed, and calving season. Costs of changing these variables can be great, and adjustments typically are made slowly. A few decisions, however, can be modified each year in response to anticipated physical and economic conditions. One such decision of importance to Gulf Coast cattle producers is when to sell calves.

[1] In the actual model, three calf production activities are permitted—cow-calf, stocker, and yearling-finishing production. Calves may be sold after each activity, i.e., as weaned calves, stockers, or slaughter animals. No calves are purchased. The only stockers or yearling-finishing animals carried are the progeny of the farm's breeding herd.

[2] This approximation with two discrete quality categories artificially lowers the comparative advantage of forages in the higher portion of either quality range.

With only minor investment in additional equipment, it is possible to carry weaned calves to heavier weights and give the producer much flexibility in timing the marketing of calves.

The LP risk model is used to estimate *E-A* efficient sets for long-run farm plans. These plans include forage system, herd size, calving season, and a long-term marketing plan. In the next phase, calf marketing is analyzed using a statistical decision theoretic approach that incorporates the LP risk model. The same three marketing options are considered here as in the long-run analysis (i.e., weaned calf, stocker, and/or finished animal sales). However, assuming that producers formulate expectations based on historical data and current information, a unique marketing decision may be made each year rather than repeatedly following the same plan.

Statistical decision theory has three components: states of nature, alternative actions, and payoffs from state-action combinations. Actions are selected to pursue an objective given the probability of occurrence of each state of nature. Higher objective values can be achieved when more accurate predictions of the state probabilities can be made from information available before an action must be selected (Halter and Dean; Eidman, Dean, Carter).

Given an objective of profit maximization, the typical approach is to (*a*) specify a discrete number of states of nature, (*b*) determine the probability of each state conditional on information available prior to decision-making time, (*c*) specify a discrete number of alternative actions, (*d*) determine the payoff from each action if a given state occurs, and (*e*) select the action with highest expected payoff, given the prior information.

In the current approach, the first two steps are basically the same as above except that a sequential decision is considered. Weaned calves may be sold immediately or retained through a stocker phase. Stockers (if there are any) may then be sold or retained through a yearling-finishing phase. For both of these phases, three states of nature with equal prior probability are specified with respect to forage supplies during the phase and calf price at the end of the phase, making a total of nine states of nature in each phase. Conditional state-of-nature probabilities depend on forage supplies and calf prices observed during the month before the selling-retention decision must be made. Conditional probabilities are computed based on eighteen years of monthly price (USDA, undated) and forage condition data (Texas Department of Agriculture).

The third step is to use the conditional probabilities to weight each specified state of nature in order to calculate an expected state given observed forage supplies and calf prices. Expected states are thus taken from a continuous rather than a discrete set of alternatives.

Fourth, a deviation is computed by subtracting a specified state from the expected state and weighting by the former's conditional probability. The number of deviations is the same as the number of specified states.

Fifth, the LP risk model is revised by the expected state and deviations in forage yields and beef prices. It is then used to select actions (from a continuous set) concerning the number of weaned calves and stockers (or stockers and finished animals) to sell in order to maximize expected net returns (payoff) subject to alternative constraints on mean absolute deviations. This procedure uses the LP model to simultaneously select an action and determine payoff given alternative risk constraints and information available at decision-making time.

The value of the predictive information is evaluated in this paper for only two sets of annual marketing strategies, i.e., portfolios providing either the highest expected net return or the lowest risk on the *E-A* efficient set. The value of information is the difference in expected net returns at a given level of risk between the annual strategy set and the long-run plan. Expected net returns of the annual strategy is the sum of each selected action's expected net returns multiplied by the probability of the information that led to the action.

Data

A good manager consistently aims for efficient production by annually culling old and open cows. Although optimal culling age depends on several variables (Bentley, Waters, Shumway), we assume for simplicity that cows are culled only after eight calving seasons or if they fail to breed. Local animal scientists' estimates of likely death losses and breeding failures for cows and replacement heifers in a reasonably well-managed Hereford-Brahman crossbred herd are reported in table 2. Based on these expectations, only 45% of cows remain in the herd through eight calvings; a 75% calf crop is obtained; 23 weaned heifers are retained annually for replacement per 100 cows in the herd, and weaned calves available for sale consist of 67% steers and 33% heifers. Two calving seasons are considered: October and February.

Estimated animal nutrient requirements, based on NRC standards (National Academy of Sciences), are adjusted by the herd's proportionate age distribution. Calves may be sold when weaned at a mean age of seven months, weighing an average of 550 pounds. If not sold, they are stocked for four and one-half months and are expected to gain 200 pounds at an average daily rate of 1.5 pounds. If retained after the stocker phase, they remain on forage an additional four and one-half months to gain another 200 pounds; they are then taken off pasture and fed a fattening ration (cottonseed meal, grain sorghum, and hay) for two months and gain 150 pounds at an average daily rate of 2.5 pounds. One bull is maintained for every twenty-five cows and replacement heifers of breeding age.

Table 2. Assumed Failure Probabilities for Cows and Replacement Heifers

	Failure to Breed	Cow/Heifer Annual Death Loss	Failure to Bear Live Calf	Calf Death Loss Before Weaning	Calf Death Loss, Weaning to Breeding
Cow	10	1	5	2	1.5
Replacement heifer	20	1	10	5	1.5

Monthly prices for the period 1955–74 are obtained from the San Antonio market for individual livestock classes—steers and heifers by weight group, utility cows, and cutter cows (USDA undated). Each price series in inflated to 1975 using the annual index of prices paid for factors of production (USDA 1972, 1976). As there was no significant trend, the average of each inflated price series for the month relevant to a particular calving season and selling activity is taken as the expected 1975 "normal" (i.e., long-run equilibrium) price for the category. Deviations in prices are computed for the same years as forage data are collected to account for forage yield-beef price interactions in the risk measure. Estimated cattle expenses exclusive of forage production costs are $69 per cow-calf unit, $20 per stocker, and $98 per yearling-finishing animal.

Forages

The unit of analysis is a 500-acre farm on the Texas Gulf Coast and is capable of producing a variety of tame forages. Twenty alternative forage activities are considered in the analysis: (*a*) perennials—common bermudagrass, coastal bermudagrass, and dallisgrass, each with two alternative fertilization rates; (*b*) mixed perennials—mixtures of the above perennials with clover, each with three alternative fertilization rates; (*c*) annuals—wheat, rye, rye-ryegrass, and two oat varieties. The alternative per acre annual fertilization rates in pounds of nitrogen, phosphorous, and potassium are 100-80-0 and 200-80-0 for the perennials and 0-100-0, 100-100-0, and 100-100-80 for the mixed perennials.

Bimonthly seasonal forage crop yields and estimated quality for three consecutive years are developed from clipping data from the Texas Agricultural Research Stations at Angleton (Riewe) and Beaumont (Ever 1973 and undated). Because stockers and yearlings as well as pregnant cows require forages with a minimum of 1.1 megacalories of digestible energy per pound dry matter in some periods, this criterion is used to separate forage yields between high and low quality categories in every period. Forage yields in all periods are adjusted downward by 20% to allow for waste due to trampling and rejection.

Nonland forage costs are adapted from Texas Agricultural Extension Service crop budgets (see Gebremeskel, pp. 176–99). They reflect 1975 costs of fertilizer, chemicals, labor, equipment, interest, and an allowance for establishment costs in the case of perennials. Nitrogen cost is calculated at $0.30 per pound, phosphorous at $0.24 per pound, and potassium at $0.075 per pound. Annual nonland costs per acre vary depending on forage type and fertilization level from $64 to $101 for the perennial forages, from $44 to $88 for the mixed perennials, and from $97 to $115 for the annual grasses.

Results of Analysis

Figure 1 presents the *E-A* efficient sets for both calving seasons examined, and table 3 reports the alternative farm organizations on these *E-A* efficient sets. The numbers of the efficient sets in the figure correspond to the farm plans in the table.

The herd calving in early spring dominates the fall calving option at all risk levels. Coastal bermudagrass with clover is the most preferred forage and is planted on at least 75% of the acreage in every efficient plan. With the high fertilizer prices in 1975, a low to moderate rate of fertilization is most profitable. No annual forages are produced. Proper forage diversification permits substantial reduction in risk with little reduction in expected net returns. Although no calves are sold as stockers, partial integration of the cattle operation through finishing permits a reduction in risk for the fall calving herd but results in increased risk for the herd calving in early spring.

The highest expected net return system on both *E-A* efficient sets is a very risky one while the lowest risk system attained by proper forage diversification, integration level, and herd size results in substantial reductions in risk with little impact on expected net returns (i.e., the *E-A* efficient sets are very steep). This is possible because (*a*) positive yield deviations from one forage can directly offset negative deviations from another in the same period and year, (*b*) positive yield deviations can offset negative yield deviations in the same year regardless of period except that the price paid for a negative deviation is about twice the price received for a positive one, and (*c*) yield deviations can offset beef price deviations of opposite sign or supplemental feed price deviations of like sign in the same year via hay purchase or sale.

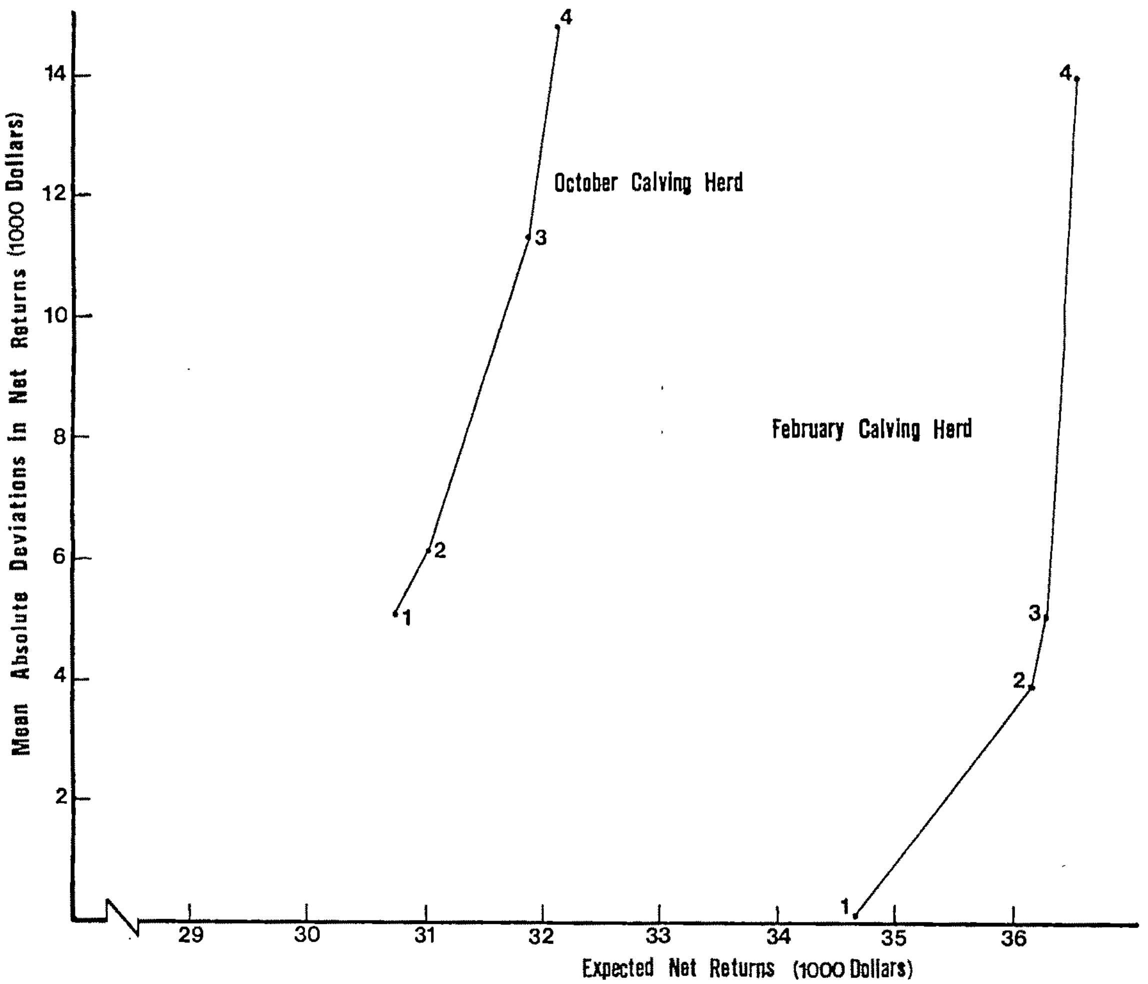


Figure 1. *E-A* efficient sets for alternative calving seasons

Only three years of data are available on forages, so the conclusions are tentative. However, a strong negative relationship is apparent among some forage yields and beef prices.

Annual Marketing Strategy

The annual calf marketing analysis is conducted on the long-run plan with the highest expected net return for the February calving herd. This farm carries 370 cows and, according to the long-run plan, intends to sell 144 weaned calves and 108 finished animals every year.

The annual decision of whether to retain calves through a stocker phase is dependent only on observed July forage conditions and not on price level. With poor forage conditions, nearly all weaned calves should be sold. Retaining calves to be sold later as stockers greatly increases risk. With normal or good July forage conditions, 84 calves are sold at weaning and the rest (67%) are carried through the stocker phase.

If any weaned calves are retained, some of them should also be carried through finishing regardless of subsequent price or forage conditions. The number, however, depends on December calf price and on both July and December forage conditions (see table 4). These generalizations emerge relative to annual strategy concerning stockers: (*a*) The better December forage conditions are, the more stockers should be held through the yearling-finishing phase. (*b*) The higher December price is, the fewer stockers should be held through finishing. (*c*) Current forage supplies are more important than stocker prices for planning the subsequent beef production system. If December forage conditions are good, December stocker price must be higher than considered here relative to expected slaughter price to discourage transfer of any calves to the yearling-finishing operation. (*d*) Given a set of current forage and price conditions, a strategy that includes finishing more calves may yield higher expected net return, but it also incurs more risk.

Table 3. Farm Organizations on *E-A* Efficient Sets, Alternative Calving Seasons

	Financial Characteristics		Livestock Production and Marketing			Forage Production[a]		
							Coastal Bermuda-Clover Mixture	
Farm Plan	Expected Net Returns (*E*)	Mean Absolute Deviations (*A*)	Breeding Herd Size[b]	Weaned Calves Sold	Finished Calves Sold	Coastal Bermuda No. 2	No. 1	No. 2
	($)	($)	(number)			(acres)		
February calving								
1	34,700	100	474	325	0	118	253	129
2	36,200	4,000	438	301	0	0	375	125
3	36,300	5,100	401	199	75	0	331	169
4	36,500	14,000	370	144	108	0	500	0
October calving								
1	30,700	5,100	348	0	236	0	382	118
2	31,000	6,300	357	35	209	0	387	113
3	31,900	11,300	409	202	78	0	387	113
4	32,100	14,800	399	203	71	0	500	0

[a] Annual fertilizer application rates:

	Nitrogen	Phosphorous	Potassium
	(lbs.)		
Coastal bermuda no. 2	200	80	0
Coastal bermuda-clover no. 1	0	100	0
Coastal bermuda-clover no. 2	100	100	0

[b] Number of cows that bear a calf (i.e., 81.3% of cows and heifers exposed to the bull).

Value of Information

The value of the price and forage information obtained in July and December is the difference in expected net return at a given level of risk between the annual strategy set and the long-run plan. Since the annual solutions are obtained for alternative July and December conditions, those results must be weighted by the joint probability of price and forage level in order to determine the value of information. Further, since solutions are obtained for each set of forage-price conditions given alternative restraints on risk, the estimated value of information is dependent on which risk restraint is selected.

Table 4. Annual Marketing Strategy—Percentage of Stockers That Should Be Retained through the Yearling-Finishing Phase

Given Forage Conditions in:		Given December Prices:		
July	December	Poor	Normal	Good
		%		
Normal	Poor	15–40	15–40	< 15
	Normal	50–70	50–70	35–50
	Good	100	100	100
Good	Poor	60–80	60–80	15–35
	Normal	100	100	30–40
	Good	100	100	100

Note: The lower and upper bounds in each case represent the lowest risk and highest expected net return strategies, respectively, on the *E-A* efficient set.

The value of information is illustrated by selecting, respectively, the highest expected net return and the lowest risk portfolios on the *E-A* efficient sets. The value of information for the highest expected net return strategy is $4,000 (11% of net return of the corresponding long-run plan). However, the *E-A* efficient set of long-run plans reaches a global maximum for *E* when *A* is $14,000 while the annual strategy set with the highest expected net return has a mean absolute deviation of $15,700. Consequently, the increase in *E* for this strategy is accompanied by an increase in *A* of $1,700, or 11%. The value of information for the lowest risk annual strategy is about $1,100, approximately 6% of the long-run plan's expected net return, given the same risk level (A = $4,000).

It should be noted that the annual marketing strategies considered here are relevant for only one long-run farm plan. There is no guarantee that a strategy yielding the maximum possible *E* for a given level of *A* has been found using the predictive information. It is possible that using the same information on a different farm plan would yield highér-valued marketing strategies. However, a similar analysis with the lowest risk farm plan produced results with no greater information value.

Summary and Implications

While this LP model is developed specifically for a Texas Gulf Coast beef producer, its features are relevant for risk analyses of other situations with

similar attributes. Weak-market intermediate products are not unique to forage produced for beef cattle grazing. Sheep, goats, and wildlife also are supported largely by forages harvested directly by the animals. Most silage is consumed on the farm by dairy and beef cattle rather than being sold. In highly integrated industries, market prices for intermediate products largely disappear (e.g., live broilers and breeding flocks). Normative investigations of such industries require consideration of the role of nonmarketed intermediate as well as marketed final products. Examination of seasonal supply and demand characteristics is important for many factors and products, e.g., labor, water, milk, and vegetables. Purchase and sale price differentials and quality variability are likewise common and make adaptations introduced in this model relevant for analysis of other risk management problems.

With regard to the implications of this study's empirical findings, it is recognized that a producer's willingness to accept higher levels of risk in order to achieve higher expected net return (i.e., his utility function) must be known before unique farm plans can be determined. However, it appears that the *E-A* efficient set facing our cow-calf producer is much steeper than has been estimated for crop producers (e.g., Hazell; Lin, Dean, Moore; Scott and Baker). This ability to reduce substantially risk with little effect on expected net return is due both to a negative relation between cattle prices and some forage yields and to the producer's ability to store forage for later consumption. If generalizable, two important implications of this finding include: (*a*) it is difficult to conceive of a personal utility function that would cause a producer to prefer a solution other than the lowest risk *E-A* efficient plan, and (*b*) traditional profit-maximizing LP solutions are unlikely to be adopted readily by cow-calf producers because they may include much higher risk levels with little improvement in expected net return than other alternatives. Consequently, ignoring risk in normative cow-calf production studies is a serious model misspecification and perhaps an even greater oversight than in crop production studies.

[Received December 1977; revision accepted September 1978.]

References

Bentley, E., J. R. Waters, and C. R. Shumway. "Determining Optimal Replacement Age of Beef Cows in the Presence of Stochastic Elements." *S. J. Agr. Econ.* no. 2 (1976):13–18.

Conrad, H. R., J. W. Hibbs, and A. D. Pratt. "Regulation of Feed Intake in Dairy Cows. II. Association Between Digestible Dry Matter Intake and Cellulose Digestibility in Cows Fed Increasing Levels of Grain Concentrate." *J. Dairy Sci.* 49(1966):1038–42.

Eidman, V. R., G. W. Dean, and H. O. Carter. "An Application of Statistical Decision Theory to Commercial Turkey Production." *J. Farm Econ.* 49(1967):852–68.

Ever, G. W. "Evaluation of Cool Season Annuals for Forage Production in Southeast Texas." Texas Agr. Exp. Sta. PR-3248, Oct. 1973.

———. "Small Grain Dry Matter Yields at the Texas A&M University Agricultural Research and Extension Center at Beaumont, 1971–1972." Mimeographed. Texas Agr. Res. Ext. Ctr., Beaumont, undated.

Gebremeskel, Tesfaye. "Cow-Calf Production and Marketing Decisions in East Texas: Application of Risk Constrained Linear Programming and Statistical Decision Theory." Ph.D. thesis, Texas A&M University, 1977.

Halter, A. N., and G. W. Dean. *Decisions Under Uncertainty with Research Applications.* Cincinnati, Ohio: Southwestern Publishing Co., 1971.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1971):53–62.

Hazell, P. B. R., and P. L. Scandizzo. "Competitive Demand Structures under Risk in Agricultural Linear-Programming Models." *Amer. J. Agr. Econ.* 56(1974):235–44.

Lin, W., G. W. Dean, and C. V. Moore. "An Empirical Test of Utility vs. Profit Maximization in Agricultural Production." *Amer. J. Agr. Econ.* 56(1974):497–508.

National Academy of Sciences, National Research Council. *Nutrient Requirements of Beef Cattle,* 4th ed. Washington, D.C., 1970.

Riewe, M. E. "Forage and Animal Production Programs for Southeast Texas." *Grasses and Legumes in Texas—Development, Production, and Utilization,* ed. E. C. Holt and R. D. Lewis, chap. 11. Texas Agr. Exp. Sta. Res. Mono. 6, Jan. 1976.

Scott, J. T., and C. B. Baker. "A Practical Way to Select an Optimal Farm Plan under Risk." *Amer. J. Agr. Econ.* 54(1972):657–60.

Texas Agricultural Extension Service. *Texas Crop Budgets: Blacklands Region.* Texas A&M University. MP-1927.

Texas Department of Agriculture. "Pasture and Range Feed Conditions, 1953–1976." Unpublished data.

U.S. Department of Agriculture. "Livestock Detailed Quotations, San Antonio Market, 1955–1974." Agr. Mktg. Serv., unpublished data.

———. *Agricultural Statistics.* Washington, D.C., 1972, 1976.

Whitson, R. E., P. J. Barry, and R. D. Lacewell. "Vertical Integration for Risk Management: An Application to a Cattle Ranch." *S. J. Agr. Econ.* no. 2 (1976):45–50.

Whitson, R. E., D. L. Parks, and D. B. Herd. "Effects of Forage Quality Restrictions on Optimal Production Systems Determined by Linear Programming." *S. J. Agr. Econ.* no. 2 (1976):1–4.

Endangered Species, Irreversibilities, and Uncertainty: A Comment

V. Kerry Smith and John V. Krutilla

There has been increasing attention given to the special features of public investments that involve an irreversible modification of a unique natural environment including extinction of a species. One of the most recent additions to this literature is a paper by Bishop calling for the use of Ciriacy-Wantrup's safe minimum standard of conservation (SMS) for these cases. In the process of developing his arguments, Bishop compares the SMS approach with the work of the Natural Environments Program at Resources for the Future (RFF) and concludes that "while the RFF group has developed somewhat different terminology (e.g., preservation alternative rather than safe minimum standard) and includes no explicit treatment of the problem of irreversibility and uncertainty in a game theory framework, the basic decision rule remains the same as under the SMS approach" (p. 16).

It would seem that Bishop's intention was to suggest that the two approaches lead to comparable decisions. Specifically, informational limitations may prevent a full implementation of the RFF decision rules. Krutilla and Fisher noted that under such conditions it may be necessary to use judgment, giving some "benefit of doubt" to the preservation alternative. Indeed, this possibility was illustrated in the examples they discussed. A comparison of the decisions rendered for such cases with those that would be forthcoming using the SMS approach led Bishop to conclude that the two approaches called for similar recommendations.[1] In what follows, we will argue that this observation does not imply that the approaches would lead to the same conclusion when they are applied with the benefit of the required information. Because one might have interpreted Bishop's observations as suggesting that the treatment of irreversibility and uncertainty in Krutilla and Fisher was simply an amendment to the SMS approach, it is important to identify the distinct differences in the two methods for evaluating these decisions.

The RFF approach is a direct extension of the conventional criteria for optimal public investment to take account of the irreversibilities associated with actions involving natural environments.[2] The formal analysis was developed from Arrow's evaluation of the optimal investment decisions of a perfectly competitive firm in the presence of irreversibilities.

In what follows, we develop our arguments by reviewing the types of uncertainty Bishop considers present in those problems associated with endangered species. Using his example, we highlight the methodological distinction between the SMS and RFF approaches. That is, our case arises when the decision maker is not sure a particular action will be irreversible. For example, the development of a hydroelectric facility may not impinge upon the life support system of an endangered species. Unfortunately, the outcome cannot be known in advance of the action. Thus decisions must be made in the presence of an uncertain irreversibility. It may be that such cases are especially important for the problems associated with endangered species.[3]

In section two of this paper we outline the differences between the Krutilla-Fisher (KF) treatment of uncertainty and irreversibility and Bishop's. The third section develops an amended version of the KF model and considers its implications for the decision criteria for those investments involving uncertain irreversibilities. The last summarizes the paper and reviews its relationship to a general class of problems which involve uncertainty and irreversibilities.

A Statement of the Issues

Bishop's arguments hold that the uncertainty associated with irreversible modifications of the reservoir of "potential resources" arises because of both

V. Kerry Smith and John V. Krutilla are senior fellows, Quality of the Environment Division, Resources for the Future.

Thanks are due Richard Bishop and an anonymous referee for helpful comments on an earlier draft of this paper. Both authors received partial support for this research from the Directorate for Applied Science and Research Applications of the National Science Foundation. In addition, Smith's work was partially supported by the Environmental Protection Agency through the Ozone Study group at the Bureau of Economics and Business Research, University of Maryland.

[1] We are grateful to Richard Bishop for clarifying his position on the relationship between the two approaches in private correspondence.

[2] Actually the Krutilla-Fisher book discusses the conceptual issues associated with endangered species but none of the case studies explicitly treated them. The applications had a primary focus on problems associated with unique natural environments.

[3] Bishop in private correspondence indicated that his work with students suggests that there may be several relevant cases, including highway development, impacting the Mississippi sandhill crane and the patterns of off-road vehicle use and the California leopard lizard.

social and natural factors. The former refers to a "lack of knowledge about future time paths for the income levels, technologies, and other variables that will determine which life-forms eventually become resources and which will not" (Bishop, p. 11). The second relates to the limited information available on the physical attributes of these resources that may make them useful for human activity. Thus, the first category of uncertainty results from the future course of economic activity and its implications for the derived demands for particular environmental resources. The second arises because we do not know all the prospective uses of these resources. It may not be possible to identify fully their characteristics. Thus it is conceivable that knowledge of the features of the natural environment will lead to the identification of new uses for resources, whose market values were previously negligible. For our purposes, it is important to expand this second category. We may not understand certain natural environments well enough to be able to judge whether or not a particular development action will have a serious enough impact to lead to extinction. This type of uncertainty was not explicitly referred to in Bishop's discussion. However, it can be considered one interpretation of his hypothetical example. Table 1 repeats his table 1 "Matrix of Losses" illustration.

Suppose that Strategy E is defined as development and, following Bishop, implies extinction of the species under consideration. If state 1 prevails, development and the associated extinction of the species has no losses, while with state 2 the losses are designated as y. The rationale for the absence of losses under state 1 is presumably a combination of what Bishop has labeled social and natural outcomes which cause the potential resource to have no economic value. Thus, an action leading to its extinction does not imply losses. One might easily redefine this strategy simply as development and then attribute the absence of losses to the fact that the action did not cause species extinction. For Bishop's analysis, the two interpretations are equivalent and the distinction would appear semantic. However, for the Krutilla-Fisher (KF) framework they are not. Thus, in the third section we use this case of uncertain irreversibilities to illustrate the nature of the differences between SMS and KF approaches.

Before proceeding to this example, it is necessary to consider other distinctions between the two methods. Bishop characterizes the decision process confronting society in a game theoretic setting (with table 1 as his example). He suggests that the SMS strategy will be equivalent to the minimax solution of a game when the social costs of SMS are "acceptably" low. According to Bishop, one of the RFF group's primary contributions to those problems which involve a choice between SMS and development was to enhance the planner's ability to define the social costs of adopting the SMS strategy.

This view is misleading. The analysis discussed in KF adopts the perspective of conventional benefit-cost utilitarian framework which addresses a single project decision. The discrete nature of the Krutilla-Fisher decision rule stems from their assumption that the investment decision relates to a unique site and that any modification to it will be irreversible (Fisher, Krutilla, Cicchetti). Thus there is little point in considering the scale of the development action. However, this same rationale may not be as appropriate for the case of an endangered species.

When the investment problem can be structured in these discrete terms, the KF argument calls for full enumeration of the benefits and costs of the investment, including the benefits foregone from the natural environment or species in its preserved state. Unfortunately, Bishop focuses on the difficulties discussed by KF in estimating each of these elements. He does not seem to appreciate the maintained assumptions in the formal models they use to derive the conditions for an optimal investment decision. That is, each model assumes that all benefits and costs have been fully described and that the nature of the uncertainty has been enumerated.

KF do observe that it may not be necessary for some cases to have complete information. The justification for a development decision may itself be marginal and a careful review of the evidence sufficient to document this conclusion. More specifically, they noted that "it is possible that we shall have marginal cases under review, in which case carrying out the evaluation of the benefits and investment costs of development will suffice. That is, if the net present value of development is negative, it should not be undertaken regardless of environmental costs. Since a complete quantitative evaluation of environmental amenity services is likely to be difficult, if not impossible, in any event, our strategy is first to analyze each development plan critically, correcting for faulty elements in the evaluation to determine if development would be justified even if there were no environmental opportunity costs. Since some proposals are likely to be inefficient whether or not environmental costs are considered such a strategy may avoid much unnecessary effort" (Krutilla and Fisher, p. 81).

The RFF decision rules can be derived from a specific statement of society's objective function, namely to maximize the discounted net benefits associated with the expenditures involved in a

Table 1. Bishop's Matrix of Losses

	States of Nature		
Strategies	1	2	Maximum Losses
E	0	y	y
SMS	x	$x-y$	x

Note: Based on Bishop's table 1, page 12, assumes $x, y > 0$.

given project, together with an explicit treatment of the irreversibility inherent in the decision. Thus, to interpret the RFF approach as one that offers only a mechanism for estimating the social costs of the SMS strategy is not correct. The only adjustment to these rules arises from the treatment of uncertainty in the decision process. An example of the KF interpretation of their findings serves to confirm this conclusion. They observed that "it will be efficient to proceed very cautiously with any irreversible modification. There is some benefit, for example, even from the point of view of one interested in maximizing the present value of the environment's resources, in refraining from irreversible development that appears warranted by relative benefits and costs when uncertainty is ignored. If "irreversible" is identified with "destructive" the implication of the analysis of irreversibility under uncertainty is similar to that of the assignment of property rights to the nondestructive uses" (Krutilla and Fisher, p. 73).

An Alternative to Bishop's Model

Assume that society wishes to maximize the discounted net benefits from the use of a natural asset. The pattern of use under consideration involves a conversion of this resource from its natural state to some transformed state and the process cannot be reversed. Assume further that there is some unknown threshold or critical zone on the size of the stock that will maintain the type of benefits it provides in the natural state.[4]

It should be noted that it is important to recognize that development will, as a rule, lead to a loss in some of the benefits associated with a natural environment or species in its preserved state. For example, a smaller species stock will provide less opportunity for viewing or other recreation-related activities. The benefits to which we refer are those that are associated with the existence of the species. It seems reasonable to assume that these will be the largest share of the preservation benefits. For our purposes we have not explicitly treated the other component of preservation benefits, because one can assume $B_d[S(t)]$ has been adjusted to reflect their effects and our conclusions remain unaffected.

While we might argue over the precise statement of the objective function, this description seems to reflect the primary attributes of the problem associated with decisions affecting the viability of endangered species. Moreover, it is consistent with Bishop's observations that his work was directly related to Ciriacy-Wantrup's class of "flow resources with a critical zone." In describing them he noted that "Such resources are renewable within limits but have a threshold or critical zone such that once the critical zone is reached, further depletion is irreversible. Wantrup placed major emphasis on the problem of uncertainty associated with irreversible depletion of critical zone flow resources" (Bishop, p. 10).

In order to maintain consistency with the general problem statement as developed by Bishop, we have respecified the Krutilla-Fisher investment model so that $B_d[S(t)]$ designates the benefits from holding $S(t)$ of the stock of a natural asset in a development form. $B_p[S(t)]$ is the preservation benefits lost from developing $S(t)$, and $I(t)$ is the investment cost for the development. These costs will be assumed to be linearly related to the physical quantity of the stock which is transformed [i.e., $\dfrac{dS}{dt} = \sigma I(t)$] and $S(t) \geq 0$.

In order to incorporate the effects of an unknown critical zone for this investment problem, assume that the threshhold level of development for the asset, $\bar{S}$, is a random variable, reflecting natural uncertainty associated with the potential resource. Moreover, suppose that $\bar{S}$ is distributed over the interval $(0, \infty)$ with $g(\bar{S})$ the probability density function. S is postulated to be independently and identically distributed through time. It is then possible to write the probability of $\bar{S} \leq S(t)$ in equation (1):

$$(1) \qquad P[\bar{S} \leq S(t)] = \int_0^{S(t)} g(\bar{S})d\bar{S} = \phi[S(t)].$$

This equation permits a straightforward definition of a modified KF objective function in equation (2).

$$(2) \qquad G = \int_0^{\infty} e^{-\rho t}\{1 - \phi[S(t)]\}\{B_d[S(t)] - I(t)\}dt + \int_0^{\infty} e^{-\rho t}\phi[S(t)]\{B_d[S(t)] - B_p[S(t)] - I(t)\}dt,$$

where ρ is the rate of discount. The first term defines the expected net benefits when the asset (or species) is not irreversibly altered by the investment. The second describes the case in which investment exceeds the unknown threshold and the modification is not reversible. Our problem is that we do not know which state will prevail.

The current value Hamiltonian for this problem is given in (3) and $\alpha(t)$ a costate variable.[5]

$$(3) \quad H_o = \{1 - \phi[S(t)]\}\{B_d[S(t)] - I(t)\} + \phi[S(t)]\{B_d[S(t)] - B_p[S(t)] - I(t)\} + \alpha(t)[\sigma I(t)].$$

Given the benefit functions are well behaved, the

[4] This model arose from discussions with Ronald Cummings on an earlier paper by Smith considering the treatment of uncertainty in the Krutilla-Fisher model.

[5] In order to focus attention on the current value of the shadow prices, we follow Arrow and Kurz and treat the infinite time horizon problem in terms of the current-value Hamiltonian. If $H(I, S, \theta)$ is designated the Hamiltonian, then $e^{\rho t}H(I, S, \theta)$ is the current value Hamiltonian designated H_o. It follows that $\alpha(t) = e^{\rho t}\theta(t)$ and is the current shadow price. See Arrow and Kurz, pp. 46–49, for more details.

necessary conditions for an interior solution are given by

$$\dot{\alpha}(t) = \alpha(t)\rho - \frac{\partial H_o}{\partial S}, \text{ and} \tag{4}$$

$$\frac{\partial H_o}{\partial I} = -1 + \alpha(t)\sigma = 0. \tag{5}$$

Equation (5) has a direct parallel in the KF model and implies that investment may only take place in free intervals defined by this equality condition. In all other cases $I(t)$ will be zero. Equation (4) offers an explicit description of the determination of the scale of investment. It is in this condition that we can distinguish the KF approach from Bishop's description of SMS. Rewritten to conform to the conditions where $I(t) \geq 0$ we have

$$B'_d = \frac{\rho}{\sigma} + \phi' B_p + \phi B'_p, \tag{6}$$

where prime designates the derivative with respect to $S(t)$. This condition suggests that the optimal increments to the stocks of the developed asset will proceed in an open interval until the marginal benefits equal the direct marginal costs (i.e., ρ/σ) plus the expected foregone marginal preservation benefits (designated by $\phi B'_p$) and the marginal costs associated with an enhanced likelihood of extinction with increases in $S(t)$ (given by $\phi' B_p$).

If we examine this condition [i.e., equation (6)], it represents distinctly different criteria from the SMS approach and is completely consistent with the earlier framework of KF. Moreover, the foregone benefit terms on the right side of (6) reflect several of the issues raised by Bishop and others for these problems including (*a*) the prospects of learning the consequences of the costs of irreversible actions through experimentation (Viscusi and Zeckhauser). This effect is represented in $\phi' B_p$; (*b*) the differences in the degree of information on B_d and B_p. Such an effect could be incorporated in the model through the specification used for ϕ; and (*c*) the treatment of investment plans for irreversible decisions recognizing the advantages of risk pooling. This can be accommodated in the specification $\phi' B_p$. In each case these modifications can have important implications for the conditions for optimal investment plans. They also serve to illustrate the manner in which the relationship between irreversibility and uncertainty can be related to the problems at hand and, in turn, affect the defined optimal criteria. This simple description illustrates how they are consistent with the general methodology proposed by Krutilla and Fisher. They result from variations in the maintained assumptions confronting the planner.

Implications

This paper has suggested Bishop's argument that for pragmatic purposes the work of RFF's Natural Environmental Program and the Safe Minimum Standard approach can be treated as leading to the same decisions is not correct. Under certain conditions the two may lead to the same conclusion. However, this alone does not imply they are equivalent for practical purposes. Even with incomplete information, the incentives for its acquisition are quite different under each approach. His arguments do not seem to recognize that the KF investment decision rules were derived from an explicit objective function with direct account taken of irreversibilities. Thus their results do consider the problems associated with uncertainty when the decision relates to a single unique area, wherein any modification will lead to an irreversible loss of the area's preservation benefits. Consideration of development decisions involving endangered species must recognize that the same "lumpiness" as was present for the case of developing a natural area may not be a feature of the problem. Indeed the decision maker may not know that the action under consideration will lead to a loss in the preservation benefits (i.e., loss of genetic information as contrasted with the loss of value from a reduced, but reproducibly viable population).

Bishop's analysis does not treat explicitly those cases where it may be possible to reduce the stock of an endangered species without necessarily leading to the extinction of that species. It is certainly reasonable to expect that for some cases small modifications to the habitat may not impair the species' life support system. Unfortunately, we often do not know in advance what the extent of such feasible changes can be. We have proposed a simple amendment to the original KF model to begin to consider optimal investment decisions in the presence of such uncertain thresholds on the irreversibility of development investments. In some respects this modification provides a middle ground between the strictly irreversible changes considered in Fisher, Krutilla, and Cicchetti and those discussed by Cummings and Norton. Indeed, the latter argued that "it may be technically impossible to restore a wooded area containing camp sites or a flooded canyon to their *exact* original state. It is not clear, however, that such exactness is a prerequisite for the future generation of recreational benefits" (p. 1022). We are not suggesting that it is possible to reconstruct a unique natural environment or "genetically engineer" an extinct species. Rather, it may be that some modifications to a particular type of natural environment, while remaining physically irreversible, do not necessarily imply that the critical elements responsible for all the preservation benefits are lost. Moreover, we may not know in advance whether these benefits will be

lost. In our judgment this is the interaction between uncertainty and irreversibility which seems most relevant to Bishop's problems. Because it has not been addressed heretofore in the literature, his paper raises an important issue by exposing another dimension of the problems of irreversible investment decisions.

[Received July 1978; revision accepted October 1978.]

References

Arrow, K. J. "Optimal Capital Policy with Irreversible Investment." *Value, Capital, and Growth: Papers in Honour of Sir John Hicks*, ed. J. N. Wolfe. Chicago: Aldine Publishing Co., 1968.

Arrow, K. J., and A. C. Fisher. "Environmental Preservation, Uncertainty and Irreversibility." *Quart. J. Econ.* 88(1974):312–19.

Arrow, K. J., and M. Kurz. *Public Investment, the Rate of Return, and Optimal Fiscal Policy*. Baltimore, Md.: Johns Hopkins University Press, 1970.

Bishop, R. C. "Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard." *Amer. J. Agr. Econ.* 57(1978):10–18.

Ciriacy-Wantrup, S. V. *Resource Conservation: Economics and Policies*, 3rd ed. Berkeley: University of California Press, 1968.

Cummings, R., and V. Norton. "The Economics of Environmental Preservation: Comment," *Amer. Econ. Rev.* 64(1974)1021–24.

Fisher, A. C., J. V. Krutilla, and C. J. Cicchetti. "The Economics of Environmental Preservation: A Theoretical and Empirical Analysis." *Amer. Econ. Rev.* 62(1972):605–19.

———. "The Economics of Environmental Preservation: Further Analysis." *Amer. Econ. Rev.* 64(1974):1030–39.

Krutilla, J. V. "Conservation Reconsidered." *Amer. Econ. Rev.* 57(1967):777–86.

Krutilla, J. V., and A. C. Fisher. *The Economics of Natural Environments*. Baltimore, Md.: Johns Hopkins University Press, 1975.

Smith, V. K. "Uncertainty and Allocation Decisions Involving Unique Natural Environments." Washington, D.C.: Quality of the Environment Division, Resources for the Future, Disc. Pap. No. D-21, 1978.

Viscusi, W. K., and R. Zeckhauser. "Environmental Policy Choice Under Uncertainty." *J. Environ. Econ. and Manage.* 3(1976):97–112.

Endangered Species, Irreversibility, and Uncertainty: A Reply

Richard C. Bishop

The comment by Smith and Krutilla provides an opportunity further to clarify the economic issues which attend public choice concerning endangered species. This clarification is made more necessary by the ambiguity in their discussion of the relationships between the RFF approach and the SMS approach. While my article may have been overly concerned with the similarities of the two approaches, their attempt to differentiate them can only leave the reader confused.

I have three goals here. First, I will carefully differentiate the two views of public choice over endangered species. Second, I will illustrate how the work at Resources for the Future (RFF) has contributed to solving the measurement problems which attend the SMS strategy. Finally, I will assess the model presented in their comment.

Comparison of the Two Approaches

Several preliminary remarks are in order. First, this reply will deal only with endangered species, and the issues discussed have only limited relevance to the much larger problem of choosing between preservation and development of natural environments. Second, the difference between "the safe minimum standard of conservation" on the one hand and "the safe minimum standard approach to public decision making" on the other deserves to be re-emphasized. The former, which has been clearly defined by Ciriacy-Wantrup, refers to a state of conservation which avoids the critical zone. As such it is a descriptive term relating to the physical and biological condition of the resource. In particular it carries no normative significance. The SMS approach, on the other hand, is a framework for public decision making about whether or not the safe minimum standard of conservation should be adopted.

My own thinking on the relationships between the RFF and SMS approaches has been helped greatly by viewing the decision process in four steps suggested to me by Daniel Bromley. Step one involves conceptualization of the problem: why is potential extinction an economic problem? Step two involves collecting and analyzing relevant data. In step three, the economist develops recommendations for the public decision maker. In step four, the decision maker takes the analysis of economists and combines it with other information and value judgments to arrive at a final decision.

The Conceptual Issue

At step one, the two approaches are clearly different. "The RFF approach," to quote Smith and Krutilla, "is a direct extension of the conventional criteria for optimal public investment to take account of the irreversibilities associated with actions involving natural environments." That is to say, the RFF approach rests on the assertion that society's desire is to achieve an efficient allocation of resources between development and preservation, in this case preservation of endangered species. Uncertainty is characterized by assuming more than one future outcome, each with known probability of occurrence and known payoff. That is to say, the RFF approach treats uncertainty as if it were risk. This means that most of the theoretical discussion relating to uncertainty deals with option value, public investment analysis under risk, quasi-option value, and other such topics.

At step one, the SMS approach views the choice problem as one of choosing between the increased future uncertainty—a cost—that will result from extinction, and the more obvious costs that may result from efforts to avoid extinction.[1] The treatment of uncertainty in this framework is strikingly different than in the RFF approach. The SMS approach begins with the game-theoretic formulation of the problem where it is explicitly assumed that the probabilities of alternative outcomes are unknown. In the game-theoretic formulation, the decision criterion is one of choosing the strategy that minimizes maximum possible losses. However, as I pointed out in the article (p. 13), even this characterization of the uncertainty problem, though useful, is not satisfactory, since it assumes that outcomes and associated payoffs are known.[2] An ex-

Richard C. Bishop is an associate professor in the Department of Agricultural Economics and the Center for Resource Policy Studies at the University of Wisconsin-Madison.

Daniel W. Bromley's incisive comments on two earlier drafts contributed a great deal to the final product. Some very helpful correspondence with V. Kerry Smith deserves acknowledgement as well.

[1] In many cases, maintaining the safe minimum standard of conservation involves no social costs. Such cases are discussed below.

[2] Bishop (1978, p. 13) also has noted that the minimax strategy

amination of natural and social uncertainty showed that it would be more realistic to assume that not only probabilities, but also potential outcomes and associated payoffs are not known. That is to say, the SMS approach treats uncertainty about the impacts of extinction as pure uncertainty. It does so through the modified minimax principle—society should choose the safe minimum standard of conservation unless the social costs of doing so are unacceptably large.

Because the choice problem involves a value judgment about intergenerational equity, economics is not equipped to address the question of how large costs would have to be before they become unacceptably large. The economist can provide insight into the nature of the economic problem posed by potential extinction and then estimate the social costs of the safe minimum standard of conservation, but society, through the means devised to deal with such matters, must judge whether or not these costs are within acceptable limits.

The RFF and SMS approaches are thus seen to be quite different in that they are based on different definitions of uncertainty. Furthermore, I would argue that the SMS approach is to be preferred because it more adequately characterizes the uncertainty which we face when we must choose a course of action that ultimately influences whether or not a life form will continue to exist. How is the social and natural uncertainty discussed in the original paper—and reviewed by Smith and Krutilla—to be reduced to a set of alternative outcomes with associated payoffs and probabilities? When the RFF approach transforms the problem to one involving only risk, it assumes away a large part of the problem, while the SMS approach confronts the problem of pure uncertainty directly. More will be said along these lines in the closing section.

The Empirical Issue

In step two of this idealized decision process, empirical evidence is gathered. Here the two approaches have many similarities. Both would examine the benefits and costs of preservation and development. Further exposition will be easier if some symbols are defined. The definitions will be consistent with Bishop (1978) and differ slightly from those in Smith and Krutilla's comment. In the original paper it was useful to think in terms of a hypothetical endangered species that would not survive if a water resource project were completed. Let B_p equal the gross social benefits of preservation minus the associated costs directly involved in preservation. These costs may include expenditures for policing of critical areas of habitat and the costs of building and maintaining trails for backpacking and hiking.[3] For the reasons emphasized in the RFF approach and reviewed in my paper, only a portion of B_p can be measured. Let measurable preservation benefits net of associated costs be symbolized by B'_p. Likewise let B_d equal the gross benefits of constructing the dam and reservoir minus construction, operation, and maintenance costs. While techniques for measuring B_d are certainly not perfect, we will assume that these benefits and costs have been adequately approximated. All benefits and costs are assumed to be in present value terms.

Both the RFF and SMS approaches would seek to measure B'_p and B_d, but the interpretation of the results would be significantly different. The SMS approach would interpret the results as the measurable social costs of avoiding extinction, here symbolized as SC. These costs are made up of the opportunity costs incurred (benefits forgone) because preservation is incompatible with building the dam minus whatever measurable social benefits can be realized from preservation. That is, $SC = B_d - B'_p$. The RFF approach would compare B_d and B'_p to gain insight about whether preservation or development is the more efficient choice. Restated, let measurable net development benefits be $NB_d = B_d - B'_p$. Then measurable net development benefits under the RFF approach equal the measurable social costs of the safe minimum standard of conservation under the SMS approach (i.e., $SC = NB_d$).

The Choice Problem

With the analysis now complete, step three involves deriving conclusions and recommendations. This may be trivial. If $B_d < 0$ or $B_d < B'_p$, then preservation is clearly the efficient choice under the RFF approach. In the SMS approach, this is equivalent to saying that the social costs of avoiding extinction are negative. Thus, the conclusion under the SMS approach would be that both the present members of society and future generations will be better off if the safe minimum standard of conservation is maintained.

If $NB_d = SC > 0$, then the problem is more difficult. Under the RFF approach it is argued that measurable preservation benefits are less than actual preservation benefits. It may be that $B'_p < B_d$ yet $B_p > B_d$ could still hold, indicating that preservation is really the efficient solution. Thus, the recommendation is to "give the benefit of the doubt" to preservation. Presumably this means that preservation should be chosen unless NB_d is sufficiently large that development is probably the efficient choice.

When $SC > 0$, then there will be a positive burden on current members of society if extinction is to be avoided. Here the SMS approach recommends that the decision maker try to assess whether this burden is within "acceptable" limits.

---

is probably overly conservative and ignores intergenerational issues. These problems were also important in deriving the modified minimax principle.

[3] It was assumed in the original article (p. 11) that activities such as hiking and backpacking would not conflict with efforts to maintain the species in question.

It is at this point that problems developed in my earlier paper. To "give the benefit of the doubt to preservation" sounds very much like "preserving unless the social cost exceed acceptable limits." In both cases the decision maker is being asked to judge whether $B_d - B'_p$ is "too large." However, this does not mean that the decision will be the same, since the definition of "how much is too much" differs depending on whether the RFF or SMS approach is employed. This brings us to step four, and the making of the actual decision.

The Actual Choice

The decision at step four could well be different under the alternative approaches because the problem was defined differently in step one. Giving the benefit of doubt to preservation under the RFF approach places the decision maker in a position of trying to correct for problems of economic measurement in order to approximate an efficient allocation between preservation and development. The question is whether option value, quasi-option value, existence value, ambiguous property rights, problems with estimating the values of future scientific research, and the like are sufficient to make $B_p > B_d$ even though $B'_p < B_d$. In the SMS approach, the decision maker is asked to express the collective willingness of society to absorb social costs in order to avoid the imposition of uncertainty on future generations. In the RFF approach, the decision maker is attempting to weigh benefits and costs, while in the SMS approach the decision maker is attempting to weigh future uncertainty against near-term costs. This difference in viewpoint might well lead to different decisions.

More on the Costs of the Safe Minimum Standard

Smith and Krutilla accuse me of making misleading claims about the work of Krutilla and others when I asserted that this work has enhanced our understanding of the social costs of avoiding extinction. The problem is more one of ambiguity in the original paper than a real disagreement. The work at RFF has been valuable in adding to our knowledge about the nature of B_p and B_d. The work on option value, quasi-option value, optimal decisions under irreversibility, and the concept of asymmetry in technological progress should all be mentioned as examples. Because $SC = B_d - B'_p$, research on the right-hand side cannot help but assist us in understanding the costs of the safe minimum standard of conservation. Hence, in addition to their significant contributions relating to irreversibilities and uncertainty in a different vein than the SMS approach, they have also aided in improving the SMS approach as an analytic aid to social choice.

Uncertain Irreversibilities

Before making some concluding remarks, let us consider the significance of the work on uncertain irreversibilities in the Smith-Krutilla comment. As they point out, this topic was not given explicit treatment in my paper. As they suggest, it is not always clear whether a proposed action will cause extinction. For example, in my own work focusing on the California condor, the scientific evidence was inconclusive on the question of whether or not the condor's chances for survival would be harmed if an open-pit phosphate mine were permitted (Bishop 1973). Thus the Smith-Krutilla analysis of uncertain irreversibilities is a significant addition to the RFF approach.

On the other hand, in discussing their model, Smith and Krutilla arrive at two conclusions with which I take exception. First, early in the third section of their paper, they suggest that uncertainty about whether extinction will result from a proposed action "seems to reflect the primary attributes of the problem associated with decisions affecting the viability of endangered species." This point arises again in the "Implications" section. "In our judgment this is the interaction between uncertainty and irreversibility which seems most relevant to Bishop's problems." I could not disagree more. The crux of the problem is the great natural and social uncertainty about the long-run effects of extinction. Uncertain irreversibility is one of those subsidiary aspects which I could not deal with in one brief paper. To elevate this secondary issue to a central place in either the RFF approach or SMS approach would be a serious distortion of the problem.

Second, Smith and Krutilla's assertion that their uncertain irreversibility model provides "a middle ground between the strictly irreversible changes considered in Fisher, Krutilla, and Cicchetti and those discussed by Cummings and Norton" is misleading. The Cummings and Norton paper has nothing to do with uncertain irreversibility as defined by Smith and Krutilla. Rather, Cummings and Norton questioned whether development activities are necessarily strictly irreversible in the sense that all future recreational and other preservation benefits would be lost wherever development is permitted. This is a relevant comment, but it is beside the point in the context of endangered species. In point of fact, extinction is probably the best example one could find of a case where the Cummings and Norton paper is not applicable because by definition extinction is strictly irreversible (barring advances in genetic engineering).

Which Approach Is Appropriate?

Should an economist who is analyzing a public choice problem involving endangered species fol-

low the RFF approach or the SMS approach? The RFF approach has the advantage of consistency with accepted practice in evaluating public investments, and it includes several concepts that appear relevant. However, the essence of the choice problem is pure uncertainty, and here the RFF approach must be considered inferior to the SMS approach. On the conceptual level (step one), the problem is largely assumed away when what amounts to pure uncertainty is transformed into risk. At step two, the pure uncertainty aspects are largely ignored while measurable impacts are given great attention. Then, when it is time to offer recommendations (step three), the RFF approach "deals with" the problem of pure uncertainty by simply admonishing the decision maker to give the benefit of the doubt to preservation. Surely the tremendous natural and social uncertainty that surrounds the long-run effects of extinction deserve more careful analytical attention than this.

At the conceptual level, the SMS approach confronts pure uncertainty directly. During empirical investigations, it more properly interprets benefits and costs as indicators of the burden on the present generation of avoiding extinction rather than as efficiency signals. When developing recommendations, the SMS approach presents the decision maker with the problem of weighing future levels of uncertainty against current levels of costs. Because the SMS approach deals more realistically with uncertainty at each step, it must be considered the more appropriate approach to problems of public choice involving endangered species.

Analytics aside, which approach will accord more closely with how we think about the future and the endowment of resources and potential resources we pass on to future generations? Which way would "they" like us to look at such issues? I submit that the SMS approach is a rather accurate analytical manifestation of the way in which difficult and uncertain intertemporal choices are actually made. It helps us in such choices through its explicit structuring of the problem of uncertainty. Intertemporal efficiency is a nice term to the analyst, but until we can do a better job of defining it operationally, it does little good to construct elegant and rigorous appearing models with that concept at their core.

The job of the economists, it seems to me, is to help society properly to conceptualize the problem—that is, to ask the right questions. The SMS approach grew out of Ciriacy-Wantrup's efforts to do just this. The current gnashing of teeth over snail darters, furbish louseworts, and Mississippi sandhill cranes might well be reduced if the issues were framed in the SMS approach. This approach would bring both structure and perspective to such debates. To do this, after all, is what resource economics is all about.

[*Received December 1978.*]

References

Bishop, Richard C. "Uncertainty and the Evaluation of Environmental Impacts: A Case Study." *Environmental Impact Assessment: Guidelines and Commentary,* ed. Thomas G. Dickert and Katherine R. Domeny. Berkeley: University Extension Press, 1973.

———. "Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard." *Amer. J. Agr. Econ.* 60(1978):10–18.

Ciriacy-Wantrup, S. V. *Resource Conservation: Economics and Policies,* 3rd ed. Berkeley: University of California, 1968.

The Potential Impact of Changes in Income Distribution on Food Demand and Human Nutrition: Comment

Karen J. Morgan

Pinstrup-Andersen and Caicedo are to be applauded for their research endeavors in the area of income redistribution and dietary adequacy in developing countries. Their analysis projected a possible impact on calorie and protein availability by income stratum caused by changes in existing income distributions. The report is hopefully a step forward to improvement of public policy directed toward the goal of improved human nutrition.

The purpose of this comment is to clarify several points of nutritional nature about which there appears to be a basic misunderstanding. Although the type of data used is not specifically defined in the paper, the reader is led to assume the data used for the analysis are consumption data as opposed to dietary intake data. If such is the case, Pinstrup-Andersen and Caicedo have consistently misused the word "intake." Intake has physiological implications and refers to the ingestion of food. The authors should have used the term "consumption" because this term refers only to the quantities of foods used from the home food supply. The form in which the food enters the home rather than the form in which it is eaten or otherwise used is the amount recorded. Due to plate waste, presence of meal guests, giving food to pets, or discarding it for any reason, the quantities of foods, and thus nutrients, calculated as being consumed by the household may overstate the quantities of foods (nutrients) actually eaten.

An even more perplexing problem with the research is the misinterpretation of the information referenced from Rueda-Williamson. The figures presented in table 2 are based on provisional allowances and not on daily requirements as Pinstrup-Andersen and Caicedo reported. Daily nutritional requirements are experimentally determined minimum amounts of nutrients necessary to support health and well being. The actual values for human requirements vary according to age, sex, and weight. On the other hand, provisional allowances are set under the assumption that requirements vary among individuals and that the variation follows a normal distribution. Allowances tend to be set high enough to meet the nutritional requirements for nearly all healthy persons in each age group in the population. There are no universal allowances; for example, protein allowances vary from country to country with a man between ages twenty and twenty-nine weighing between 65 and 70 kilograms (kg) having an allowance of 65 grams in the USA, 70 grams in Australia, and 68 grams in Colombia. The FAO has developed a set of standards which are the most universally accepted; these standards state that a man of age twenty-five weighing 65 kg has a protein allowance of 46 grams. If the researchers' analyses for table 2 were based on FAO standards, there would be no nutritional risk for any income stratum. Even when the analysis is based on the allowances specified for Colombia, there is no basis for Pinstrup-Andersen and Caicedo to conclude that the low income people of Colombia have calorie and protein deficiencies. Mathematically, the two lowest income strata would be found to be below 100% of the specified Colombian allowances, but failure by a population group to meet 100% of the allowance does not necessarily establish the presence of deficiencies. The authors have no basis for speculating on these deficiencies for the above-mentioned reasons and, also, because their analyses are based on consumption data and not dietary intake data. The most they can conclude is there exists a possibility of low income people in Colombia being at nutritional risk since protein and calorie consumption are somewhat less than allowances.

The empirical analysis is limited to protein and calories; however, Pinstrup-Andersen and Caicedo suggest the methodological approach allows the incorporation of other nutrients. It is strongly urged that analysis be developed to include other nutrients since the National Institute of Nutrition of Colombia reported that with the exception of iron and vitamin C and barring the best-educated and wealthiest class of society, almost every stratum of the populations suffers from multiple nutrition inadequacies. However, it may not be feasible to use the researchers' methodological approach for such an analysis. The present model allows analysis for only one nutrient at a time. Optimum health is dependent on the correct balance of a multitude of nutrients (Scrimshaw and Young). Furthermore, the body utilization of one nutrient is interdependent on the intake of many nutrients. For example, if assessment indicates sufficient protein consumption but deficient calorie consumption, in body utilization analyses protein intake would be found

---

Karen J. Morgan is an assistant professor in the Department of Food Science and Human Nutrition, Michigan State University.

The author thanks Stanley G. Miguel for helpful comments on an earlier draft of this note.

to be low since the consumed protein would be utilized for energy instead of body-building mechanisms (Sukhatme, Beaton, Swiss). Another example of existing interrelationships is when dietary protein intake is lacking, the two proteins that play a role in the transport of vitamin A are not made by the liver in adequate amounts; thus, the esterified form of vitamin A remains stored in the liver, unavailable to the other body tissues. A deficiency may then appear in spite of the fact that the intake of the vitamin would be sufficient if protein nutrition were adequate (Scrimshaw and Young). These examples indicate the need for further development of the researchers' model. It is suggested that perhaps the use of seemingly unrelated regression analyses or more ambitious methods specifying structural interdependence on an a priori basis would aid in resolving this problem.

In their concluding remarks, Pinstrup-Andersen and Caicedo recognize and briefly note the limitations of their analysis with regard to considerations of intrafamily distribution of food and the multiplier effects of changes in food supply and consumer incomes. However, in their discussion section they extend their conclusion far beyond the limit of their empirical analysis. With references to table 3, the authors conclude that by increasing the incomes of the lower stratum, the adequacy of their diets (they incorrectly speak of nutritional impact, which, as previously discussed, is not appropriate for data used in the analyses) will be improved. This is an incorrect statement in light of the income elasticities reported. The food group of butter and margarine had the greatest income elasticity and processed foods had the third largest income elasticity. Addition of these food groups would not markedly enhance the quality of diets. Granted that beef, pork, eggs, and milk did have rather high income elasticities, but so did the nonfood group. These findings are supported by Rueda-Williamson who clearly stresses the existence in Colombia of an excessive consumption of manufactured soft drinks which pretend to virtues they do not possess and thus replace nutritious food. Thus, redistribution of income and increased food supply may not be the complete answer to eliminating malnutrition in developing countries. Based on the Pinstrup-Andersen and Caicedo analysis, it appears public policy development based on redistribution of income and increased food supply must be accompanied by strong emphasis on nutrition education if the economic programs are to be beneficial to malnourished people of developing countries. Further research would then be needed to determine fully the effectiveness of income redistribution accompanied by nutrition education programs.

In conclusion, Pinstrup-Andersen and Caicedo's economic analyses are generally good and they are to be commended for their novel and potentially useful endeavor to assess relationships between income redistribution and possible improvement of dietary adequacy in developing countries. However, it is recommended that before further research is initiated in this area, economists need to become more knowledgeable about nutrition and/or collaborate in research with nutritionists. Finally, a technical point is the consistent misuse of the term calories. Particularly glaring mistakes are made in tables 5, 6, and 7 where consumption is stated in terms of "cal/day." The figures reported refer to kilocalories per day and not calories per day.

[*Received September 1978; revision accepted October 1978.*]

References

Archivos Latinoamericanos de Nutrition, vol. 17, p. 255, Sept. 1967.

Beaton, G. H., and L. D. Swiss. "Evaluation of the Nutrition Quality of Food Supplies: Prediction of Desirable or Safe Protein: Calorie Ratios." *Amer. J. Clinical Nutrition* 27(1974):485–504.

Colombia, Republic of (Instituto Nacional de Nutrición). "Informe sobre los Problemas de Nutrición de Colombia: los Programas Desarrollados del 7 de Agosto de 1966 hasta Julio de 1967 y los Planes para el Desarrollo de Futuros Programas." DIR-67-13. Mimeographed. Bogotá, 1967.

"Dietary Allowances for Australians," 1965 revision. *Medical J. Aust.* 1(1965):1041.

National Academy of Sciences. Recommended Dietary Allowances, 8th ed. Washington, D.C., 1974.

Pinstrup-Andersen, Per, and Elizabeth Caicedo. "The Potential Impact of Changes in Income Distribution on Food Demand on Human Nutrition." *Amer. J. Agr. Econ.* 60(1978):402–15.

Rueda-Williamson, R. *The Applied Nutrition Program: The Basis of the National Nutrition Plan.* Bulletin of the Pan American Health Organization, 67, no. 3, pp. 187–200, 1970.

Rueda-Williamson, Roberto, Jose Obdulio Mora-Parra, and Franz Pardo-Tellez. *Recommendaciones de Consumo de Alimentos para Colombia.* Instituto Colombiano de Bienestar Familiar, INV-69-05, 1969.

Scrimshaw, N. S., and V. R. Young. "The Requirements of Human Nutrition." *Scientific American* 235 (1976):51–64.

Sukhatme, P. V. "Incidence of protein deficiency in relation to different diets in India." *Brit. J. Nutr.* 24(1970):477–87.

United Nations, Food and Agriculture Organization. "Protein Requirements." Rome: FAO Nutrition Meetings Rep. Ser. No. 37, WHO Tech. Rep. Ser. No. 301, 1965.

The Potential Impact of Changes in Income Distribution on Food Demand and Human Nutrition: Reply

Per Pinstrup-Andersen

Dr. Morgan brings out a number of points about which she feels there is a basic misunderstanding. In this reply, I shall react briefly to each of these points in the order in which they appear in the comment.

The data used for the analysis refer, as stated in the article (p. 405), to quantities consumed, prices paid, and family incomes, size, and age distribution. It is correct that the words intake and consumption have been used interchangeably in the article. Insofar as the results of the analysis are concerned, the correct term probably would be "actual" or "expected" family purchase. It is also correct that intrafamily distribution of the food purchased as well as food waste, meal guests, and use of the purchased food for pets introduce uncertainty in the data. Attempts were made to obtain data that were free from uncertainties; but, as everyone who has been involved in household surveys knows, there are severe difficulties associated with obtaining good consumption/intake data. I believe the quality of the raw data is as high as may be expected from household surveys, and I have no evidence that they are biased one way or the other. Casual observations indicate that the amount of food used for pets and the plate waste among the sample families were very low, and if people visit each other for dinner, the bias could go in either direction.

Now to the "misinterpretation of the information referenced from Williamson." Unfortunately, my copy of the paper by Williamson, Mora-Parra, and Pardo Tellez disappeared in moving from Colombia, and I do not have access to the paper in Copenhagen. Therefore, I cannot quote directly from it. However, as I recall, the data reported by the Williamson group were defined as the estimated calorie and protein requirements for the Colombian population taking into account the age and sex distribution, body weight, and possibly other factors influencing the calorie and protein requirements. Under the assumption that the distribution of these factors for the Colombian population was valid for the sample population, I fail to see the misinterpretation. It is very possible that the data reported by Williamson, Mora-Parra, and Pardo Tellez may be too high, particularly in the light of recent findings regarding protein requirements. But that is a different matter. At the time of initiating the analysis, it was felt that the calorie and protein levels reported for Colombia were preferable to more global FAO data. That, of course, is a judgment. Finally, I might add that a series of other studies support our findings that a large portion of low income families in Colombia suffers from energy-protein malnutrition.

I fully agree that the model would be improved greatly if the interaction among nutrients is taken into account. This is true not only for other nutrients, but also for the energy-protein interaction. Attempts to meet protein requirements without meeting energy requirements might result in utilization of protein for energy. This is not a relevant issue in the Cali analysis, because an elimination of the protein deficiencies by means of conventional foods also would eliminate calorie deficiencies. This would not necessarily be the case if we were concerned about such things as protein fortification, changing amino acid compositions in foods, and so forth. Such things were not included in the Cali analysis. I agree that there is a need to develop further the model to take account of the interdependencies in amounts of nutrients. It is also a question whether one should deal with protein requirements as such or rather look at the amount of net utilizable protein in percentage of the calorie intake. The latter undoubtedly would be more relevant in the light of findings from recent work.

Dr. Morgan states that in light of the income elasticities it is incorrect to conclude that increasing incomes in lower income strata would have a positive nutritional impact or—as phrased by Dr. Morgan—would improve the adequacy of their diet. But the income elasticities are positive and relatively large for all food commodities in lower income strata. Furthermore, the income elasticities of calorie and protein intake are very large for low income strata. This implies that additional incomes will greatly increase calorie and protein intake, or, if you will, consumption. It further implies that, because the income elasticity is positive for all foods, increasing incomes will not result in a reduction of the consumption of one food, e.g., milk, in favor of a higher consumption of another item, e.g., soft drinks. The data do not in any way support the argument that increasing incomes among low income consumers would replace more nutritious foods in favor of manufactured soft drinks. There may be an increase in the consumption of soft drinks as incomes increase, but there is no evidence that soft drinks replace more nutritious food. Finally, while the price per calorie or gram of protein

may be high for processed food there is no reason to believe that such food is always of an inferior nutritional quality. For the above reasons, the analysis of the Cali data does not support Dr. Morgan's argument that strong emphasis must be placed on nutritional education if the economic programs are to be beneficial to malnourished people of developing countries.

With respect to the "consistent misuse" and the "glaring mistakes" related to the use of the term calories, I fail to see the significance of Dr. Morgan's argument. The term calories is used in lieu of kilocalories in a very large proportion of the literature related to applied nutrition, including a number of FAO publications. Some FAO publications, e.g., *The Fourth World Food Survey*, use calories and kilocalories interchangably. While this is technically wrong, I do not see any possibilities for misunderstanding, insofar as applied nutrition is concerned.

Let me finally assure Dr. Morgan that I agree with the need for close collaboration between nutritionists and economists in the area of nutrition planning, policy, and economics. It is my experience that such collaboration can be of mutual benefit.

[*Received November 1978.*]

References

Pinstrup-Andersen, Per, and Elizabeth Caicedo. "The Potential Impact of Changes in Income Distribution on Food Demand and Human Nutrition." *Amer. J. Agr. Econ.* 60(1978):402–15.

United Nations Food and Agriculture Organization. *The Fourth World Food Survey*. Rome, 1977.

Williamson, Roberto Rueda, Jose Obdulio Mora-Parra, and Franz Pardo Tellez. *Recomendaciones de Consumo de Alimentos para Colombia, 1969*. Bogotá: Instituto Colombiano de Bienestar Familiar, INV-69-05.

Books Reviewed

Adams, F. Gerard, and Sonia A. Klein, eds. *Stabilizing World Commodity Markets*. Lexington, Mass.: D.C. Heath, 1978, xvii + 21 pp., $24.95.

This book presents a selection of papers given at a 1977 conference of the same name sponsored by the Ford Foundation. The conference's goal was "to bring together the people from these two worlds—the practical world of policy making and the world of economic theory and econometric modeling. The theorists and econometricians would become more aware of the real problems and issues. The policy makers would get a perception of the potential of more formal schemes of theory and modeling." The papers all relate to UNCTAD's proposed Integrated Programme for Commodities (IPC), either because they deal with the specifics of the proposal or are concerned with one (or a subset) of the commodities included in the IPC. The book cannot be judged in terms of this goal; only future research methods, results, and eventual policy decisions will reveal its success. However, this goal does provide a useful review criterion: do the assembled papers provide a balanced view of progress and problems on the modeling and theory of commodity stabilization schemes as well as insights into the political and market realities in which such schemes must operate? With this goal in mind, the papers selected by the editors are a curious mixture of summaries of previous research, of new research approaches, of theory, of political realities, and of alternative proposals.

Papers dealing with some aspect of commodity modeling comprise the bulk of the editors' selections. Papers by Labys and Klein summarize effectively the range of models employed in analyzing stabilization questions in commodity markets and the problems attendant to their construction and use. Two examples of single commodity, econometric models and subsequent simulations are included, one for rice and one for coffee. These papers include no actual econometric results and only summarize some simulation results, although there are references to appropriate sources. Thus, while these papers demonstrate how simulation techniques can be applied usefully to stabilization questions, they do not provide insights into the complex questions of alternative model structures and/or their implications. Two or three different models of the same market would have provided more insight into these difficult questions, thereby making the book a more useful introduction to these methods. Finally, papers by Adams and Behrman extend the single commodity modeling to multicommodity systems, the former with linkages back to a system of country-specific, macro-models and the latter as a direct evaluation of a ten-commodity version of the IPC with a Common Fund. These papers are both interesting and provocative.

The editors have also included a group of papers on the theoretical aspects of stabilization schemes. These papers, by Turnovsky, Sarris and Taylor, Smith, and Burmeister, summarize effectively the theoretical literature to date. The potential gains and losses from stabilization schemes are extremely sensitive to one's view of the structural characteristics of the market of interest.

The final group of papers focuses discussion upon the political and market realities of negotiating stabilization schemes both for single commodities and for multicommodity programs. As these papers clearly demonstrate, actual stabilization schemes are not as easily created as their simulations. Yet, it is these papers which are most problematical when reviewing the book. Taken together, these papers leave the reader feeling that stabilization schemes are infeasible politically. Certainly the historical evidence supports this view and each of the authors contribute insights into the rationale for these failures. Some also suggest alternatives (e.g., revenue stabilization) which appear more workable than price stabilization. However, one is left with the uncomfortable feeling that economists are the sole source of and support for these proposals and that policy makers are their chief opponent. It is unfortunate, given the objections of the book, that the views of those policy makers who are proposing these schemes and who are involved in these negotiations have not been included. This, of course, is not necessarily the fault of the editors. But, it must mean that the book and perhaps the conference from which the book emerged falls well short of its goal.

Anne E. Peck
Stanford University

Hexem, R. W., and E. O. Heady. *Water Production Functions for Irrigated Agriculture*. Ames: Iowa State University Press, 1978, xvi + 215, $8.95.

Hexem and Heady have brought us another, rather typical research report from the Iowa Center for Agricultural and Rural Development. In the late 1960s the authors undertook an ambitious project to develop production functions for irrigation water across a wide spectrum of climates and soils in the western states using a standardized methodology. This book reports the results of that research.

The book is organized into five sections covering thirteen chapter titles. The first section of three chapters presents us with a "Readers Digest" ver-

sion of Heady's classic text in production economics, plus his work with Dillon. Neoclassic production functions are quickly reviewed using applications to irrigation water. The final chapter in this section briefly reviews the body of theory for plant-soil moisture relations which has been developed in the past two decades by agronomists and economists. The authors do an excellent job of explaining how critical the timing of irrigation water application is to plant growth and how the same quantity of water applied under different irrigation regimes will produce a different total output (probably the one factor which makes irrigation water unique as an input).

In the next section—chapters 4 and 5—however, the authors ignore all their own good advice and assume away probably 75% of the problem by designing their experiment so that irrigation water is applied on a prespecified criterion based on soil moisture tensionmeters and/or the physiological condition of the plant. The authors would have made a significant contribution to the literature had they designed their experiment to estimate the efficiency frontier with respect to the placement and measurement of these tensionmeters.

The third section contains four chapters which report, respectively, the results of corn, wheat, cotton, and sugar beet experiments at various locations. A general format is followed in each chapter where a particularly well-fitting function is utilized to develop production surfaces, isoquants, isoclines, and marginal product curves for water and nitrogen for the crop under consideration. Calculated R^2 and F tests are all good but tend to decline from the beginning to the end of each chapter.

Hexem and Heady fall into an expository trap when drawing their response surfaces in this third section. Although none of their empirical data show a decreasing total return to water or fertilizer, the response surfaces are drawn reflecting the third state of the production function. Extrapolating beyond one's data is still considered a "no, no" among production economists.

The chapter on sugar beets is the one of most interest to a production economist due to the joint product nature of the output; namely, beet tops, beet roots, and sugar content.

Chapter 10, "Generalized Production Functions," makes significant contribution to the literature and will be of interest to most economists. The authors were faced with the problem of combining the results of experiments conducted at many different sites with wide variations in climate and soils. Using a sequential procedure plus the addition of soil and climate variables, they estimate a generalized production function for water and nitrogen.

The one important variable they neglected, however, was water quality. Water quality (salinity) is a problem of varying seriousness throughout the southwestern United States and other arid parts of the world. To ignore this variable and the concomitant leaching requirements used in managing saline irrigation waters in a generalized production function is considered by this reviewer a serious defect in this study. Most experimental test plots conducted on state agricultural experiment stations and field stations suffer from the same defect. In searching for an experimental site where as many variables as possible can be controlled, research directors tend to choose the finest soils in the area—not typical soils but rather the best soils. A problem of transferability is created. Hexem and Heady argue that their generalized production function is transferable to any site where data on their environmental variables are available. This assertion is subject to question for any site where Class I soils are not present. Nowhere do they show how their results can be transferred to soils which are of lower quality due to impediments to drainage, top soil depth, or texture.

The final section develops derived demands for water for several of the commodities studied, as well as supply functions for the commodities themselves, using the estimated production functions. The final chapter appears to have been appended to the book as an afterthought. Here it is shown how linear programming can be used to develop normative derived demand functions for water and then discusses the possibility of interbasin water transfers.

It is not clear for whom this book is intended. For the production economist, there is little new information that Heady has not already published. It should prove useful, however, to those teaching undergraduate courses in production economics as a reference and source of empirical examples. For the agronomist contemplating the estimation of production functions for irrigation water, the book is a bit skimpy, with insufficient references for additional study.

One final comment, all of the source and summary tables are on microfiche in a pocket on the back cover. The authors are to be commended for this attempt to reduce the cost of the book, but I found in using them, the fuss and bother of first locating a microfiche reader and then locating the proper tables on the microfiche to be a significant handicap to using the book.

Charles V. Moore
ESCS, NEAD
University of California

Kravis, Irving B., Alan Heston, and Robert Summers. *International Comparisons of Real Product and Purchasing Power*. Baltimore: Johns Hopkins University Press (for the World Bank), 1978, ix + 264 pp., $20.00, $7.50 paper.

Comparing national income between countries always has been tricky, and previous attempts at

tackling the problem have met with little success. The issue became urgent for the international agencies because of the currency-exchange rate upheavals of recent years. Member countries' contributions to the budgets of the agencies depend on their national product. Aid donors need comparative figures of total and per capita income. Analytical studies of economic development are impaired if national product data cannot be compared with confidence.

The volume before us is the second published from the United Nations' International Comparison Project. The first volume, titled *A System of International Comparisons of Gross Product and Purchasing Power* is written by the same three authors and Zoltan Kennessey. It concentrates on the method of comparison as applied to ten countries: Colombia, France, the Federal Republic of Germany, Hungary, India, Italy, Japan, Kenya, the United Kingdom, and the United States, with 1970 as a reference date for all ten countries and comparisons with 1967 for six among them.

The volume under review adds six more countries: Belgium, Iran, Republic of Korea, Malaysia, the Netherlands, and the Philippines, with benchmark data referring to 1973. A third phase of the project aims at increasing significantly the proportion of the world for which real-income comparisons are made. Plans beyond that are not yet fully formulated. A journal article by the three authors of this volume (*Economic Journal,* June 1978) sketches a short-cut method to extend the estimates to countries for which no benchmark investigations are made. A companion pamphlet to this book, entitled *The International Comparison Project* (a World Bank publication, *Summary,* 24 pp.) gives a brief survey of the project.

The aim of the enterprise is to replace the traditional technique of converting national-product data in national currencies by their exchange rates with a system of international prices leading to estimates in international dollars ($I). The U.S. economy comes out with the same sum of international dollars as in U.S. dollars for the whole economy but not for all its sectors. Choice of the U.S. economy as a standard is not of any particular significance for the results. Any other country could have served as "*numéraire,*" and the comparison between countries would have come out the same.

The difficulty of international comparisons is not so much in finding prices of many individual commodities and services from many countries, but rather in finding comparable quality of the commodities and services to which the prices relate. Automobiles and house rent presented special difficulties.

Comparisons are binary or multilateral. Binary comparisons between the United States and each of the other countries proceeds through computing of purchasing-power parity (PPP) for each of numerous categories (of goods and services). The PPP represents the geometric mean (usually unweighted) of the price ratios for the item; it gives the number of units of the country's currency that have the same purchasing power for the category as a U.S. dollar. For some categories such as education and health care, a simplifying procedure had to be followed.

Binary comparisons are not all that is needed to compare many countries with each other. Making binary comparisons between any two countries in a large group risks becoming unmanageable. For sixteen countries there are already 120 possible pairs (formula: number of pairs $= \frac{n(n-1)}{2}$, where n is the number of countries). For multilateral comparisons, price and quantity indexes were first computed at the level of detailed categories, and thereafter the indexes were averaged. By a method called "country-product-dummy" (CPD) all available prices were used. International prices were then estimated by a procedure devised by R. C. Geary and S. H. Khamis. Weights were used which allow each of the countries under study to affect the calculation—in a way that reflects not the size of the country itself but the prevalence, world wide, of countries with the same economic structure.

Data and procedures are discussed in detail in chapter 2, with lists of categories and items, pages 54–65. Methods of analysis are presented in chapter 3, while results are shown in chapter 4 for multilateral comparisons and in chapter 5 for binary comparisons. Some relations between quantities are shown in chapter 6. A glossary and an index facilitate use of the volume.

A wealth of useful information is presented in the numerous tables which fill a large part of the book. Reading detailed results requires close attention to the statistical criteria variously specified throughout the volume. Enough of the results are similar, in tables resulting from different approaches, to warrant conclusions, even for those who do not follow every step in the statistical treatment. Germany did not catch up with the United States in real per capita income. In 1970 and 1973, it stood at about 80% of the U.S. level. France, with a softer currency than Germany, made more real gain in the same three years and was close behind Germany in real per capita income in 1973. Japan made even larger gains in the same years, but without catching up with Germany or France in 1973.

For the food sector, there is basic agreement between multilateral comparisons (table 4.12, p. 119) and binary comparisons (table 5.33, p. 222) that both low income and middle income countries gained points in per capita food consumption relative to the United States between 1970 and 1973. Thus, the food gap was narrowing, as far as country averages are concerned (distribution within countries is not touched by these analyses). The poorest group (Kenya, India, the Philippines, and Korea) had 10% of U.S. per capita consumption, but over

one-fourth of its food consumption (in value terms) and rising by two percentage points 1970–73.

In a work of this kind, a reviewer cannot go into much detail to check accuracy and adequacy of data treatment, computations, and analysis. This reviewer did not uncover any skeletons; and, as far as the scope of the project goes, the work appears to fill the bill for its intended purposes.

It is a different matter that a reader should not expect more from these revisions of national-product pricing than is within the intent of the project. The United Nations International Comparison Project is pathbreaking for international comparisons of national product as conventionally understood, and it would be asking too much that it also should question the conceptual bases on which conventional national accounts rest. Recent efforts in the United States and elsewhere represent different dimensions, such as what to do with production for own consumption other than farmers' food (which is now the only such production included in national accounts), or how to tackle the index-number problems deriving from rising quality or efficiency of goods produced at no higher cost than before. Such problems must be solved at the level of several nations before they too may be the object of international comparison projects.

Folke Dovring
University of Illinois

Krutilla, John V., Anthony C. Fisher, with Richard E. Rice. *Economic and Fiscal Impacts of Coal Development, Northern Great Plains*. Baltimore, Md.: Johns Hopkins University Press, 1978, xix + 208 pp., $16.00.

The primary purpose of this book is to assess quantitatively a variety of policy-dependent economic, demographic, and fiscal impacts of coal development on economies and political subdivisions of two counties within the Fort Union coal formation in eastern Montana—Rosebud and Big Horn counties. Although they are recognized as significant, the study does not address directly environmental or cultural impacts. The book contains nine chapters.

The quantitative assessment reported in this book is developed by use of a multiregional, multi-industry, econometric forecasting model developed by Curtis Harris. In chapter 2, after dismissing several alternative approaches, the authors provide a general overview of the model and its key behavioral relationships. In essence, the model is based on the concept of Ricardian rent. As coal-mining activity develops in the two study counties, location rents arise within those economic sectors that produce goods and services linked to the mining activity. Such transitory rents trigger locational shifts as firms relocate closer to their markets and to reduce transport costs. Within the study counties, these movements result in increased employment and population, which in turn give rise to greater economic activity, income, property values, tax revenues, and public service requirements.

Chapter 3 presents projected economic and demographic impacts from 1975 to 1990 based on four coal development scenarios. These include: Scenario I, continuation of the present (1975) level of development of 20 million tons of coal per year; Scenario II, an increase of 22 million tons of annual production by 1980, in line with coal industry plans; Scenario III, a significantly larger increase consistent with "project independence" goals; and Scenario IV, a development pattern that includes mining for export and the construction of on-site power plant facilities and a coal gasification plant. Economic and demographic impacts of each scenario are presented graphically in this chapter. As expected, the development scenarios requiring the most productive inputs give rise to the greater economic and demographic changes within the study area.

Fiscal impacts are related to economic and demographic changes through the unique governmental structure of the political jurisdiction under consideration. A detailed discussion of a model of Montana tax legislation is presented in chapter 4. In chapter 5, the impact on state revenue estimated from this model for each development scenario and type of tax is projected to 1990. As would be expected, these impacts follow the same relative pattern as the projected economic and demographic changes for each assumed scenario.

In chapters 6 through 8, the econometric model is extended to estimate coal-related tax revenues (direct and indirect) and expenditures of local governments. Special attention is given to revenues and expenses of schools, but estimates are also derived for Rosebud and Big Horn county governments, as well as the communities of Colstrip and Forsyth, for each of the alternative scenarios. This extension is accomplished by using a school population model (assuming constant average costs per student) and community revenue and expenditure equations estimated by ordinary least squares.

Model results indicate significant impacts in terms of employment, income, and population as a result of coal development in the study counties. Under the extreme case (Scenario IV), employment is estimated to double in Big Horn county and to increase two and a half times in Rosebud county over 1975 levels. Similar population increases are projected to 1990. The impact on Montana's state treasury is positive and significant, with projected coal related revenues that would represent a significant fraction of total revenue of the state. Required state expenditures are not estimated, but the authors conclude that the impact on state government would be overwhelmingly favorable.

Big Horn and Rosebud county governments are

projected to experience quite favorable revenue-expenditure balances under each scenario and the assumed taxation and expenditure policies. Projections for towns, urban communities, and school districts are somewhat less certain; but the authors conclude that while these entities may have difficulty in financing public services imposed on them, the receipts available in the state treasury for mitigating local effects of coal developments and related activities would be quite ample for the task.

The Harris model utilized in this study is one of several alternative models being employed to estimate economic, demographic, and fiscal impacts of such developments. A major weakness of the Harris model, as used in this study, that also would limit its usefulness in other applications is the failure to account for the distribution of impacts to areas outside the political jurisdictions under study. Coal mine and power plant employee residence patterns simply do not conform conveniently to county boundaries. A most extreme example specific to this study area is the estimate that over 80% of the coal mine employees in the Decker area of Big Horn county reside in Sheridan, Wyoming (Wieland, Leistritz, Murdock). Similar patterns have been observed in North Dakota and Texas. Failure to recognize such residence and commuting patterns results in overestimates of expenditure requirements of the study counties and their subdivisions and underestimates for all impacted areas outside the study counties. Hence, policy implications of estimated net revenue-expenditure balances and recommendations for distribution of state revenues intended to mitigate local impacts are likely misleading.

The authors of this book have addressed an important problem. Strip mine coal developments are occurring in numerous areas throughout the U.S. and are likely to increase in the future. Estimation of impacts of such developments is a significant research need that should contribute to more efficient responses to change by all levels of government. The authors provide a valuable service by identifying key economic and fiscal variables and interrelationships that must be considered in such impact analyses. Although the study is limited to the unique development situation and governmental structure of Montana and the model suffers from the aforementioned shortcoming, this book should prove instructive to social scientists and others involved in evaluating economic and fiscal impacts of large resource developments.

Lonnie L. Jones
Texas A&M University

Reference

Wieland, James S., F. Larry Leistritz, and Steve H. Murdock. *Characteristics and Settlement Patterns of Energy Related Operating Workers in the Northern Great Plains*. Dep. Agr. Econ, Stat. Series No. 32, North Dakota State University, Oct. 1977.

Singh, Inderjit. *Elements of Farm Management Economics*. New Delhi: Affiliated East-West Press, 1977, 133 pp., Rs. 10.50.

This book is precise, simple, and useful to students of farm management. Organized in six chapters, the book explains practical application of principles of production economics and business management to farm businesses.

The book opens with a brief review of concepts. Farmers are assumed to work rationally to maximize profit. This simple assumption makes subsequent discussion easy, but it also limits the scope of the book. The discussion on the distinction between production economics and farm management is a little ambiguous, but the conclusion seems to be correct. Chapter two describes various production relationships, with suitable examples. Determination of the optimal level of factor use, factor and product combinations, and principles of equimarginal returns have been well illustrated. Discussion on cost is confined to short-term concepts; there is only a passing reference to long-run costs. Useful additions are examples of deriving isoquants, expansion paths, and shifts in cost curves due to economies of scale and technological change.

The next two chapters present the tools of farm business analysis and farm planning. The coverage is full, simple, and straightforward, well supported by practical examples. Among measures of farm size, "net worth" of the farm may be the latest addition.

Usefulness of linear programming for farm management is demonstrated in chapter five and compared with budgeting and functional analysis, but graphical solution is deceptively simple and conceals many complexities in the use of programming techniques for farm planning.

Finally, a chapter on farm finance explains with simple examples the principles and methods of financing the farm business. Concepts of returns, repayment capacity and risk-bearing ability, and use of financial ratios are explained fully. Some details on project evaluation covering IRR and BC ratios make the discussion complete. Related concepts of present value of future returns and discounting have already been discussed in chapter three.

In general the book is useful to undergraduate students and others interested in farm business management. To use the book, however, a basic knowledge of calculus and the principles of production economics is essential. *Elements of Farm Management Economics* would be a good supplement to a course in theory of farm management.

V. Rajagopalan
Tamil Nadu Agricultural University, India

Sosnick, Stephen H. *Hired Hands: Seasonal Farm Workers in the United States*. Santa Barbara, Calif.: NcNally and Loftin, 1978, ix + 453 pp., price unknown.

Depending on one's expectations, a reader could be either quite interested in or turned off by Sosnick's book. If one expects a tight theoretical and empirical treatment of farm labor issues from an economic perspective, he will be disappointed; this is not the author's thrust. Instead, the purpose is explicitly descriptive, the implied readership is a general one, and the message is decidedly normative. The opening page states the purpose as follows:

> The subjects of our study are the seasonally hired hands—especially those 300,000 who depend on seasonal farm work for a living. Some are migrants who travel hundreds of miles from farm to farm. A large number are people who commute from their homes to temporary farm jobs in the vicinity. Economically and socially they are a special group of workers and we will attempt to depict who they are, how they live, and what problems they face on and off the job. (p. 3)

One might argue that this could best be done by an applied anthropologist or sociologist if not by a journalist (e.g., Dunbar and Kravitz), and that competent economists such as Sosnick have comparative advantage elsewhere. This is perhaps for Sosnick himself to decide; he obviously felt that the private benefits (a good part of which may be nonmonetary) exceeded the private costs. Beyond this, however, the paucity of literature on seasonal farm labor suggests that there could be social benefits from this type of effort. A check of the "Books Received" by the *AJAE* from 1974 through 1978 indicates that only 4 of the 639 submissions appear to deal centrally with seasonal farm labor, including migrant labor. Of these, two were historical (Stein, Reisler), one was evidently British (Gasson), and one was on Chicano workers (Briggs, Fogel, Schmidt). With this degree of latitude, a reviewer has to be content with looking for sins of omission or commission rather than arguing that the author should have written a different type of book. Even economists can (and perhaps should) write tracts, but they should not forget their economics in the process.

Judged by these criteria, *Hired Hands* (an almost familial term which seems misplaced as a title) is a mixed bag. In its favor, it does give coverage to both supply and demand for seasonal farm labor as well as the implicit and explicit nature of the work contract, although these topics usually are stated in popular terms (e.g., chapter 4 is "Obstacles to Leaving Seasonal Farm Work," chapter 13 is "Field Sanitation"). Nine chapters treat the supply side (3–5, 7, 9, 10, 21–23), while another seven discuss the search process and conditions of the work contract (6, 8, 12–16). Demand generally is assumed away except for chapter 11 on "Overhiring." The content of all of these chapters is basically descriptive; skimming can be expected to have pay-off for those who wish to know about minimum wage laws, labor contractors, housing, placement services, Social Security, Unemployment Insurance (UI), welfare coverage, and laws governing aliens. "What is" and "what should be" are freely intermingled, but this is less bothersome than the fact that many of the statements of fact appear somewhat dated due to heavy reliance on congressional testimony and other documents from the 1967–71 period. Despite updating for recent major changes (e.g., extension of UI to some farm workers in 1978), one gets the definite feeling that the manuscript may have gathered dust for a while prior to publication. This feeling is reinforced by the analysis of data collected in 1966 from work crews in the Sacramento Valley (appendices to chapters 3, 9, and 10).

Perhaps the section of *Hired Hands* that is of most general interest describes the evolution of the United Farm Workers movement from 1952 through 1977. Aside from outbreaks of adulation ["Relatively few people have substantially changed the course of human events. One who has is Cesar Chavez, founder of the UFW." (pp. 297–98)], the material in chapters 17 through 20 is useful for historical perspective. Central to this section is development and resolution (?) of the conflict between the UFW and the Teamsters, the former with their much greater threat to managerial prerogatives and their use of secondary boycotts. Although the book will be useful to some as a reference on institutional matters, I have three major concerns. First, it seems far more accurate to attribute the gains by workers to competition between the UFW and the Teamsters, rather than to just one of the competitors (chapter 19 is "The UFW's Accomplishments"). Secondly, the book looks backward, rather than forward. Without downgrading the usefulness of the descriptive and historical thrust, any book "designed to become the standard authority on agricultural labor in the United States" (back cover) must deal much more thoroughly with the interactions between technological change, labor supply and demand, and unionization. My most serious concern, however, is that far less attention than necessary is paid to the issue of illegal aliens in agriculture. Even by the author's own figures (p. 7 and p. 432), undocumented workers might constitute half of the seasonal work force in California. The magnitude of their numbers in the United States, the uncertainty posed by INS "raids," the huge wage differentials and a porous border cause this to be "the" seasonal farm labor issue, and I was disappointed that Sosnick essentially passed on this topic.

Joe B. Stevens
Oregon State University

References

Briggs, Vernon M. Jr., Walter Fogel, and Fred H. Schmidt. *The Chicano Worker*. Austin: University of Texas Press, 1977.

Dunbar, Tony, and Linda Kravitz. *Hard Traveling*. Cambridge, Mass.: Ballinger Publishing Co., 1976.

Gasson, Ruth. *Mobility of Farm Workers*. Cambridge: Cambridge University, 1974.

Reisler, Mark. *By the Sweat of Their Brow: Mexican Immigrant Labor in the United States, 1900–1940*. Westport, Conn.: Greenwood Publishing Co., 1976.

Stein, Walter J. *California and the Dust Bowl Migration*. Westport, Conn.: Greenwood Publishing Co., 1973.

Tyner, Wallace E., and Robert J. Kalter. *Western Coal: Promise or Problem*. Cambridge, Mass.: Lexington Books, xii + 181 pp., $18.00.

The issues surrounding proposed development of western coal resources are diverse. Questions concerning the environmental and socioeconomic impacts of development have been the focus of considerable debate as have questions concerning the most appropriate coal-leasing program to insure efficient development while obtaining a fair return for publicly owned resources. The book title does not indicate which of these dimensions will be examined. In chapter 1, however, the authors make clear that their purpose is to develop an analytical framework for evaluating public coal leasing strategies and that the evaluation criteria will be improving efficiency in developing the resource and securing an equitable return to the public treasury. Clearly, then, the book addresses an important and timely topic in natural resources policy.

The book is organized into seven chapters. After a brief introduction, the authors describe a simulation model which is used to evaluate various leasing alternatives. The model, incorporating geologic, engineering, and economic relationships to simulate private-sector response to various public policy alternatives, is presented in chapter 2. Uncertainty in future resource prices, investment and operating costs, and the amount of reserves discovered on a given tract is accounted for using Monte Carlo techniques. The model description is clear and concise. While the extensive use of mathematical notation and equations in this chapter may pose problems for some readers, the model's general structure and logic should be understandable even to those without substantial mathematical backgrounds.

Costs of coal production are a key input to the simulation model. An engineering approach was employed to develop estimates of costs for major activities in the surface-mining operation and to estimate the effects of various geologic and policy variables on those costs. The procedures employed are described in chapter 3, and specific cost estimates for a wide range of mine sizes and geologic conditions are presented in appendix tables.

The amount and characteristics of western coal resources under public ownership are estimated in chapter 4. Special emphasis is given to areas that have been nominated by the coal industry for future lease sales. The authors point out several ownership factors which will affect future leasing policy, particularly the checkerboard pattern of federal-private subsurface (mineral) ownership found in some areas and the separation of surface and subsurface ownership which is common in most areas. These institutional factors may make it difficult to assemble coal reserves sufficient to support a mine of efficient size and, hence, may lead to a reduction in the prices bid for federal coal leases. The consideration of these institutional factors makes this study much more realistic than some earlier efforts.

The major findings of the study are presented in chapter 5. Six alternative competitive coal-leasing systems are evaluated and compared to the present cash bonus system. Major criteria for comparison are the system's effect on the probability of development for leases with various characteristics and the system's effect on the residual economic rent (after-tax net present value) accruing to the mining company. Several alternatives reduce residual rent substantially and have little effect on the probability that leases would be developed. These systems, then appear worthy of further consideration.

The issue of speculative acquisition and holding of coal leases also is examined in chapter 5. Contrary to popular opinion, the authors conclude that it is unlikely that speculative holding based on anticipated coal price increases actually occurs on a large scale. The authors also conclude that the current 2560-acre maximum limitation on new coal leases may prevent significant economies of scale from being realized in new mining operations.

A final major issue associated with coal leasing, the extent of leasing likely to be required to meet future energy demands, is addressed in chapter 6. The authors find that total strippable reserves are adequate to meet anticipated demands in every western supply area. In most areas, the coal lands already nominated by industry would be "sufficient to handle the maximum forecast demand for new capacity through 1985" (p. 129).

In summary, the book fulfills its goals admirably. The analysis is rigorous and the interpretation of results quite perceptive. The effective integration of quantitative analysis and key institutional factors makes it the outstanding work to date on the subject of western coal-leasing policy. The authors also

point out areas for further research. Areas of particular interest are the need for more refined geologic and ownership data on western coal, leasing experiments involving unitization of surface and subsurface rights, and further detailed analysis of selected leasing alternatives. The book should be useful to researchers and especially to natural resource policy makers.

F. Larry Leistritz
Texas A&M University

Institutional Members, 1978

American Agricultural Economics Association

Agway Foundation

C. C. Dennis, Rep.
P.O. Box 4933
Syracuse NY 13221

Amstar Corporation

Saul Kolodny, Rep.
1251 Avenue of the Americas
New York NY 10020

American Cyanamid Company

H. W. Jamison, Rep.
P.O. Box 400
Princeton NJ 08540

Anderson, Clayton and Company

Allen Ater, Rep.
P.O. Box 2538
Houston TX 77001

Arthur D. Little, Inc.

Robert Ellsworth Lee, Rep.
15 Acorn Park
Cambridge, MA 02140

Cargill, Inc.

David B. Arnold, Rep.
Cargill Building
Minneapolis MN 55402

Caterpillar Tractor Company

J. F. Shaner, Rep.
101 Northeast Adams
Peoria IL 61629

Central Soya

C. Lockwood Marine, Rep.
1300 Fort Wayne National Bank Building
Fort Wayne IN 46802

Chemical Bank

Peter W. Siverson, Rep.
1 World Trade Center, Suite 8321
New York NY 10048

Chicago Board of Trade

Lloyd Besant, Rep.
LaSalle at Jackson
Chicago IL 60604

CIBA-GEIGY Corporation

Elmer C. Hunter, Rep.
P.O. Box 11422
Greensboro NC 27409

Connell and Company

W. A. Cromarty, Rep.
45 Cardinal Drive
Westfield NJ 07092

Continental Grain Company

Ted Rice, Rep.
277 Park Avenue
New York NY 10017

Deere and Company

R. Gerald Saylor, Rep.
John Deere Road
Moline Il 61265

Des Moines Register and Tribune

Gilbert Cranberg, Rep.
Des Moines IA 50304

Doane Agricultural Service, Inc.

Eldon Dixon, Rep.
8900 Manchester Road
St. Louis MO 63144

Farmland Industries, Inc.

W. Gordon Leith, Rep.
P.O. Box 7305
Kansas City MO 64116

Federal Land Bank of St. Louis

S. D. Sajban, Rep.
Main P.O. Box 491
St. Louis MO 63166

Food Marketing Institute

Tim Hammonds, Rep.
1750 K Street, Northwest
Washington DC 20006

Harvest Publishing Company

Daton H. Matlick, Rep.
9800 Detroit Avenue
Cleveland OH 44102

Hunt-Wesson Foods, Inc.

D. D. Rohdy, Rep.
1645 West Valencia Drive
Fullerton CA 92634

Indiana Farm Bureau Cooperative Association, Inc.

Philip French, Rep.
120 East Market Street
Indianapolis IN 46204

Land O'Lakes, Inc.

Donald Ault, Rep.
614 McKinley Place
Minneapolis MN 55413

Merck and Company, Inc.

Roger S. Toussaint, Rep.
P.O. Box 2000
Rahway NJ 07065

Northwestern Mutual Life Insurance Company

Glenn W. Buzzard, Rep.
720 Wisconsin Avenue
Milwaukee WI 53202

Oscar Mayer and Company

Patrick J. Luby, Rep.
P.O. Box 7188
Madison WI 53707

Peavey Company

Sherman L. Levin, Rep.
Peavey Building
730 Second Avenue South
Minneapolis MN 55402

Pillsbury Company

Richard T. Crowder, Rep.
Executive Offices
Minneapolis MN 55402

Ralston Purina Company

Norman M. Coats, Rep.
835 South Eighth Street
P.O. Box 1606
St. Louis MO 63199

Royal Bank of Canada

H. D. McRorie, Rep.
Box 923
Winnipeg, Manitoba CANADA R3C 2T5

Safeway Stores, Inc.

Paul A. Baumgart, Rep.
Oakland CA 94660

Southern States Cooperative

Claud L. Scroggs, Rep.
P.O. Box 26234
Richmond VA 23260

United Grain Growers Ltd.

A. M. Runciman, Rep.
Box 6600
Winnipeg, Manitoba CANADA R3C 3A7

Wilson and Company, Inc.

Leonard J. Haverkamp, Rep.
4545 Lincoln Boulevard
Lincoln Plaza
Oklahoma City OK 73105

American Journal of Agricultural Economics

Volume 61 Number 3

August 1979

AAEA Annual Meeting
Washington State University
Pullman, Washington
29 July–1 August 1979

The *American Journal of Agricultural Economics* is published five times a year (February, May, August, November, December) by the American Agricultural Economics Association. Prior to 1968, this *Journal* was the *Journal of Farm Economics.*

Printed for the AAEA by Heffernan Press, Inc., Worcester, Massachusetts, USA.

Second class postage paid at Lexington, Kentucky, and additional mailing offices, Pub. No. 019500.

Editorial Policy

The purpose of the *Journal* is to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscripts should have a relationship to the economics of agriculture, natural resources, or rural and community development. Contributions, methodological or applied, in the business, extension, research, and teaching phases of agricultural economics are equally encouraged.

Editorial Communications

All manuscripts and editorial correspondence, except as noted below, should be addressed to the editor, V. James Rhodes, Department of Agricultural Economics, Mumford Hall, University of Missouri Columbia, MO 65211

Communications concerning book reviews and books submitted for announcement in the *Journal* should be sent to the book review editor, Herbert H. Stoevener, Department of Agricultural Economics, Oregon State University, Corvallis OR 97331.

American Journal of Agricultural Economics

Volume 61 Number 3

August 1979

Articles

Notes

Books Reviewed

Articles

Resource and Environmental Constraints to Growth

V. Kerry Smith and John V. Krutilla

To evaluate conventional methods for modeling the role of natural resources in economic activities, this analysis reviews the specific attributes of past and current neoclassical models that included natural resources, considering both micro analyses of extractive firm behavior and aggregate optimal planning models, and examines conventional assumptions about constraints to economic activities including both the availability of production materials and the absorptive capacity of environmental resources. An optimal allocation of natural resources (all the original endowments of the earth) requires a conjunctive management strategy so that both the rates of extraction and waste generation are considered.

Key words: economic growth, environmental common property resources, natural resource availability.

Ever since the Reverend Thomas Malthus predicted a grim resolution of the seeming contradiction between the exponential growth of population and the finite resource base, his thesis continues to make its intermittent appearance in economic discussions as well as in the practical affairs of the work-a-day world. Perhaps an early postwar indication of this concern is reflected in two presidential commissions (i.e., the Water Policy Commission in 1950 and the Materials Policy Commission in 1952) as a result of the concern evoked by the rate of materials consumption during World War II. Almost simultaneously, however, there appeared a most interesting paper by T. W. Schultz on the declining importance of agricultural land that contradicted in spirit the need for the large-scale land reclamation recommended by the Cooke Commission as necessary to feed a growing population. At about the same time, culminating in a somewhat later publication, a team of researchers at Resources for the Future under the leadership of Harold Barnett were extending the implicit message of the Schultz paper across all extractive industries.

The importance of the Barnett-Morse study, *Scarcity and Growth: The Economics of Natural Resource Availability*, derives from its wide influence on the thinking of economists and policy makers alike. Their evaluation of the trends in "real unit costs" and relative prices over the period 1870 to 1957 concluded that there was no evidence of increasing resource scarcity. Simply stated, four factors were suggested to explain why potential increases in the relative costs of natural resource commodities had been avoided. First, when higher grade sources are exhausted, lower grade sources are found in greater abundance. Moreover, the qualitative differences among various stocks diminish with the lowering of the grades of the materials. Second, as a particular extractive resource becomes more scarce, the rate of increase in its price tends to be offset by substitution of other resources.[1] That is, users seek alternatives with more favorable cost re-

V. Kerry Smith and John V. Krutilla are senior fellows, Quality of the Environment Division, Resources for the Future.

Smith's research was begun originally with RFF support and has since received support from the John Simon Guggenheim Memorial Foundation and the Ford Foundation. Further support to both authors has been provided by the Directorate of Applied Research of the National Science Foundation.

An earlier version of this research benefited from the comments of K. J. Arrow, H. J. Barnett, W. J. Baumol, E. N. Castle, R. C. d'Arge, R. Day, B. C. Field, A. C. Fisher, F. M. Fisher, R. Haveman, G. Heal, A. V. Kneese, C. Morse, P. Portney, C. S. Russell, V. Ruttan, T. Sandler, T. W. Schultz, W. D. Schulze, M. Sharefkin, R. M. Solow, J. Sonstelie, and W. Spofford.

[1] Scott described the process in terms of characteristics and noted that "demand for minerals is derived from demand for certain final goods and services. Therefore, certain properties must be obtainable from raw materials from which such services and types of final goods are produced. Man's hunt for minerals must properly be viewed as a hunt for economical sources of these properties (strength, colour, porosity, conductivity, magnetism, texture, size, durability, elasticity, flavour, and so on)" (p. 81).

lationships and all but the more insistent demands for the resource are reduced or eliminated. Third, increases in price stimulate greater search activity to locate new deposits and provide incentives for greater recycling which can reduce the pressure on sources of virgin materials. Fourth, technical change is directed toward reducing the costs of providing natural resource commodities either through reductions in the extraction costs for existing deposits or the introduction of methods which make previously uneconomic resources a part of the effective reserves at current or near term future prices. (See Herfindahl; Landsberg, Fischman, Fischer; or Morse.)

The Barnett-Morse study was conducted against a background of optimism. The conventional wisdom accepted the presence of an advanced and continuously advancing technology wherein the materials problem was fundamentally only a problem of abundant and low-cost energy. Indeed, with the advent of nuclear power, confident predictions of power producible at such low costs as not to warrant metering formed the backdrop for the optimism that motivated research in the area of evaluating resource availability.

As a general matter economists have tended to accept the view that the same factors that were responsible for relaxing materials constraints in the past will continue. For example, Houthakker (1976) has recently observed that "the ancient concern about the depletion of natural resources no longer rests on any firm theoretical basis" (p. 12). In Solow's (1974b) neoclassical framework, the continuous advances in technology, along with substitution among different kinds of inputs, allow the economic resource base to expand, i.e., the stock of resources itself is not limited in either size or composition, with the result that per capita material well-being is in principle capable of continuous improvement.

These conclusions derive from models which depict society's supply options in terms of a simplified view of resource endowments and of production activities. In the case of the production technology, conventional practice calls for the use of an aggregate production function. Thus, it is prudent to review the adequacy of both the concept of such an aggregate relationship and the specific form of the function used to aggregate micro-level production information. Both of these issues are examples of a larger set of problems involving the conventional practices of economists in characterizing the nature of the physical, technical, and institutional constraints on economic activity. The production technology is but one component of these and, along with the restrictions imposed by the state of our natural endowments, will exhibit technical and/or physical properties that influence the means selected to maintain human welfare.

Consider the first of these limitations, the perception of natural resources. Typically, natural resources are defined as those commodities which exchange on primary commodity markets. Indeed, it is only from such market transactions that past analyses have obtained the empirical data for analysis of the scarcity and growth issue. Thus the analysis of resource adequacy has been limited to only those resources whose ownership is vested in private parties. The whole range of common property resources has been omitted from our system of accounts. Among these are important elements of the basic life support system, some of which are renewable, albeit not necessarily augmentable, and some of which are neither renewable nor augmentable, and hence subject to resource depletion in a manner that parallels many of the private property resources. Accordingly, even if the early analyses suggesting that there has been relaxation of the private property resource constraints are accepted as correct, there is still reason to question these conclusions because their analytical framework fails to recognize that such gains may have been achieved at the expense of reductions in the stock of common property resources potentially yielding life support services. Thus, continued faith in the cornucopian promise of technology may need to be modified in important respects.

In order to develop these thoughts, we first review the neoclassical models for examining the role of natural resources in economic processes with special reference to the conceptual treatment of natural resources. This discussion is followed by a review of the nature of physical constraints conventionally embodied in economic models. In section four, we consider the valuation system implied by economic models and its implications for intertemporal efficiency and fairness. In the fifth section, we evaluate the empirical analyses of resource adequacy relative to our proposed broadened definition of natural resources. The

last section provides a summary and an appraisal of the potential importance of these issues.

The Role of Natural Resources in Neoclassical Models

In describing the neoclassical approach in modeling the role of natural resources in economic activity, it is important to distinguish those efforts devoted to modeling the behavior of a firm engaged in extractive activities from those associated with describing a simple economy with natural resources treated as a factor input. As a general rule, the research associated with the first class of models has been directed toward analyzing, in a positive context, the effects of external influences on the firm's behavior including market structure (Hotelling, Stiglitz 1976, Schulze), taxes (Burness, Stiglitz 1974b), and uncertainty (Heal, Gilbert). See Peterson and Fisher for a complete review. By contrast, research with the second type of model generally has attempted to examine the implications of the special nature of natural resources as a nonrenewable input to the process of economic growth and the evaluations of the welfare implications (in a planning context) of different extraction patterns (Solow 1974a, Dasgupta and Heal, and Dasgupta). Indeed, the two approaches are reinforcing when directed to the evaluation of the optimality of different allocation systems, such as private markets, for utilizing the exhaustible resource.

Firms within the first class of models generally are assumed to be profit maximizers subject to a variety of external influences. The models of these firms are distinguished by their relaxation of one or more of the restrictions to behavior in order to consider its effects on the optimal extraction patterns for the resource. For example, Stiglitz (1976) has shown within a partial equilibrium setting that a (mining) firm facing a constant elasticity demand curve (for extractive outputs) will supply the same amounts of a nonrenewable resource regardless of the market structure (i.e., competitive or monopoly) in which it operates.[2] His analysis requires a number of simplifying assumptions, among the strongest of which is negligible extraction costs. Because it is also possible to show (Stiglitz 1974a) that under general conditions the competitive firm will offer an intertemporally efficient use profile for a nonrenewable resource, one implication is that there are conditions under which market structure will not distort the efficient profile of resource extraction. Intertemporal efficiency in this context means that the present value of the marginal product of natural resources net of extraction costs will be the same at all points in time. Because these findings are important and easily overinterpreted, it is useful to appreciate their limitations as well. For example, in order for intertemporal efficiency to be maintained, all of the values—positive and negative—associated with the extraction and use of the natural resource must be mediated through market transactions. Not only can static externalities interfere with this conclusion, but through market transactions, as Sandler and Smith (1976, 77) note, there may be cases in which intertemporal externalities also occur in the allocation of resources. Under such circumstances, the private market solution resulting in equality of these present values will not necessarily be intertemporally efficient.

There are two further aspects of this class of neoclassical model that should be considered. The first of these concerns the nature of the demands for extractive outputs. Kamien and Schwartz (1977) have extended the Stiglitz results to show that if one accepts that natural resources are basically no different from other factors of production, then the iso-elastic demand functions facing these mining firms must be derived demands. Their results indicate that these demand conditions require that all the production activities that give rise to the demands for the extractive outputs must be represented by a Cobb-Douglas production function. Thus, incompatible uses of a natural resource (i.e., *in situ* common property final consumption services) cannot be reflected by the postulated demand structure for the services of natural resources.

At a general level this issue concerns the implications of the use of aggregate models for representing diverse motives for demanding extractive outputs, and indirectly, then, the conclusions derived using them on the desirability of market behavior. Because these models require that all economic activities involved in using the extractive outputs are

[2] One must assume, of course, that the absolute magnitude of the elasticity is greater than unity.

motivated by cost minimization subject to a Cobb-Douglas production function, we encounter squarely a substantive aggregation problem. There are a number of special dimensions to this problem which bear directly on the ability of these models to contribute to useful judgments concerning the importance of natural resources. For example, one might well question the extent to which a conventionally defined production function can represent a sequence of engineering processes involved in the transformation from inputs to outputs (see Marsden, Pingry, Whinston for a discussion of this point). Two recent efforts suggest that these problems have formidable implications for both the definition of factor inputs and for the measurement of the features of the production technology. The first of these, by Lau, examines the conditions required for a consistent index of aggregate materials inputs. In concluding the evaluation of the theoretical restrictions required for direct and indirect (i.e., using duality theory) methods, Lau argues that there is little prospect for defining a consistent materials aggregate over all sectors. In independent empirical analyses, Kopp and Smith find that even when the technology is defined correctly, the improper aggregation of materials inputs introduces substantial distortion in the measured features of the production technology.

A second level at which such issues arise, that is closer to the manner in which aggregation issues are conventionally raised, relates to the aggregation of production functions across different firms using the extractive outputs. In this case, we find that very restrictive conditions, i.e., Solow-Fisher criteria (F. M. Fisher 1969), must be satisfied if one is to assume that a single aggregate production function relating total output to measures of the total levels of each input used is to exist. (See F. M. Fisher 1969, Houthakker 1955–56, Johansen, Levhari, and Sato for further discussion.) Moreover, the implied aggregate substitutions can result from changes in the distribution of capital intensities across the microunits, and can represent cases where there is no actual possibility for substitution in the microtechnologies themselves. Indeed, technical and/or institutional factors must be considered in judging the reasonableness of these implied aggregate substitutions.

Similar questions can be raised with the aggregate models where the implications of the availability of natural resources for the level and growth of real economic output are directly associated with the importance and degree of substitution possibilities for natural resources (Solow 1974b). Both of these characteristics arise as properties of an aggregate production function in such models and, as we suggested above, may be deceptive indicators of the technical possibilities actually available to an economy.[3] These issues are especially important to these planning models because the sensitivity of the economy at an aggregate level to the exhaustion of a resource input depends on the properties of the aggregate production function at the extreme levels of input use. That is, all of these models suggest that the maintenance of a constant per capita income or maximization of discounted utility requires limitless substitution (with the elasticity of substitution at least unity) of either labor or capital for the exhaustible resource. If the natural resource is necessary or essential to production processes, then the optimal plans will not fully deplete available suppiies. However, even in these cases we find an unrealistic view of the role of resources because the models characteristically assume production can take place with infinitesimal, but nonzero, quantities of the natural resource. While such smooth mathematical substitutions are convenient analytically, they may well grossly misrepresent the available technological options.

A related issue bearing directly on the ability of aggregate production functions to portray adequately the importance of natural resources in production processes follows from recent work by Cummings and Schulze:

> Current treatments of the Ramsey problem with limited resource availability ignore a fundamental restriction, however, which arises naturally from the problem itself: the conservation of mass-energy. Most of these works make use of Cobb-Douglas production functions . . . wherein it is implicitly assumed that capital stocks are perfectly substitutable for the rate of natural resource availability. The conservation of mass requires that the mass of output be no greater than the mass of inputs. . . . Since the nature of capital and labor's contribution to the production process is that of altering the resource mass or converting energy content to material or work output, the relevant balance restriction concerns output and resource use. (pp. 1–2)

The authors reflect these attributes by including in a conventional neoclassical model

[3] The recent simulation experiments of Fisher 1971, and Fisher, Solow, Kearl lend considerable support to this conclusion.

mass balance constraints. Alternatively, one might interpret these limits to substitution as a limitation on the range of application of the economist's models of production activities using the production function.

Thus, it appears that in both classes of models conventional neoclassical formulations are used with only the names of the inputs altered. This strategy fails to consider explicitly whether there are unique features associated with the use of natural resources that make such structures ill-equipped to deal with the problem. Moreover, when the perception of natural resources is extended to include common property resources, then our questioning of the conclusions of the models and the associated policy implications is further justified. We shall discuss two problems raised by ignoring the role of the nonpriced services of common property resources for neoclassical modeling of the role of natural resources. Quite aside from the inability of such limited formulations to portray all aspects of behavior, this partial view of the character of natural resources can introduce both theoretical and empirical biases in the results. Consider the analysis of the mining firm. Improvements in the state of the arts governing the firm's ability to extract larger quantities of a constant quality ore or to tap lower grade deposits may be at the expense of greater use of the services of common property resources. One of the methods used in measuring the effects of technical change calls for allocating the gains in productivity to all measured inputs. (See Nadiri for a review.) Because the services of common property resources do not exchange on organized markets, they are omitted by these methods, with corresponding theoretical biases associated with both the modeling efforts and any empirical results.

The difficulties introduced with the expanded definition of resources in the manufacturing processes using extractive outputs to fabricate final consumption goods are equally striking. Omitting consideration of common property resources' services as a type of natural resource input implicitly assumes either (*a*) that these services make no direct contribution to the production of the measured outputs, or (*b*) that these services can be measured by assuming they are proportional to raw material inputs. Under the first of these assumptions, one might argue that we could treat the role of common property resources in either of two ways. If their function is to serve as receptacles for the residues of the production process, then modeling might proceed by measuring their use as inputs or alternatively identifying dispersal medium-residual combinations as joint outputs with the marketable products. This specification assumes that the services of common property resources are used only as receptacles of industrial effluents, which is clearly unacceptable in an aggregate context. It ignores their role for amenity, recreational, and for that matter, life support services.

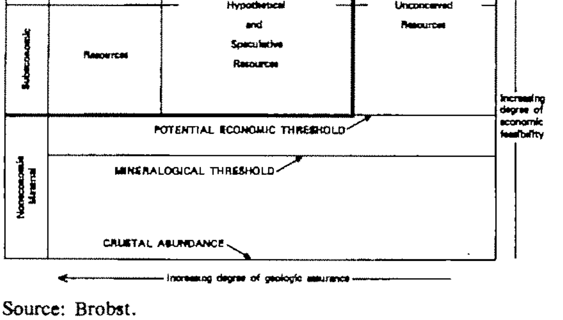
By contrast, the proportionality assumption implies common property resources are separable from all other inputs. This characteristic requires that the marginal technical rate of substitution between the raw materials and common property services of natural resources is independent of the levels of usage of all other factor inputs at all levels of output. Under this framework it is possible to estimate the characteristics of the production technology if we also assume that the correct proportionality weights are constants. Moreover, the estimated characteristics of the technology will differ from the true by a scaling factor (i.e., the unknown factor of proportionality). We cannot leave the issue at this. One must inquire as to how likely these assumptions are to be satisfied. Here, again, even casual empiricism suggests that judgments can be made. Common property resources' services are generally different from raw materials and their functions in the production technology are likely to be quite different from those of materials inputs.

Unfortunately, if we abandon these restrictive assumptions we must then admit all past estimates of the production technology, and technical change may be biased in an unknown way. That is, the previous production technology estimates have been based on models with the specification error of omitted variables. If we assume the level of use of the services of the common property resource (or resources) varies over the sample, then the estimates of the remaining parameters associated with priced inputs can be biased and the implications of the results midleading. Moreover, we might expect from a simplified view of the process of technical change, using an induced innovation framework, that new techniques will be selected in order to substitute nonpriced services of common property resources for those which are priced (Ruttan, Smith 1972, and Magat). This behavior would

suggest that the past failure to account for the role of common property resources in the description of the technology has imparted progressively more serious biases as a result of the induced changes over time.

In order to understand the issue of availability of materials, it is necessary to appreciate the difficulty in quantifying the unknown. That is, while our knowledge of the geological structure of the earth's crust has improved dramatically with the improved exploration techniques and the accumulation of information, there remain substantial gaps in our basic knowledge. It is therefore not surprising to find a diversity of accounting schemes and estimation methods for projecting the quantity of a given material. Recently Brobst and Harris and Skinner have provided overviews of the issues associated with defining in a systematic way the quantities of a resource available at a given time. Figure 1 reproduces the taxonomy adopted by the U.S. Geological Survey to classify the types of known information about material stocks.

Two aspects of this classification scheme, involving the factors which influence the estimates of the available supplies of a material at any given moment in time, are important to its use. The first of these relates to the state of knowledge concerning the physical composition of the earth's crust. In simple terms, how much do we know about the location, amount, and quality of various deposits of materials? Equally important, what have been the characteristics of the earth's crust where these deposits have occurred and to what extent can we expect similar occurrences elsewhere? This latter issue is particularly important when



Source: Brobst.

Figure 1. U.S. Geological Survey's classification of mineral resources

one recognizes that all areas of the earth have not been completely explored for mineral deposits (see Harris and Skinner for more detail on this issue).

Variations in estimates and maintained hypotheses concerning the physical deposition of materials are great. One of the most important of the accepted tenets of conventional wisdom (the first explanation of the Barnett-Morse results) must therefore be considered to be only one of several competing hypotheses. Both the Brobst and Harris-Skinner papers make it clear that there is now equal evidence which conflicts with the view that progressively greater quantities of lower grade materials are always available. Rather, there may be significant differences in the distribution of the geochemically abundant metals compared with the scarce elements. The less geochemically abundant minerals, the ones where increasing demands may pose serious problems, may well follow a bimodal distribution. This view would imply that after the richest grades are exploited, the quantity available would decline rather than increase at lower grades. Equally important, this hypothesis concerning the availability of minerals means that we may reach a level of ore concentration where the scarce element occurs only as "an isomorphous substitute" and cannot easily be concentrated. At the present stage of knowledge this possibility is a strong competing hypothesis which requires further geological research in order to evaluate its validity and, if it is valid, the implications for the availability of minerals.

It is, of course, possible that recently legislated controls on air and water emissions will induce new technologies to be developed which will make relatively less extensive use of the services of common property resources. However, it is not possible to make a clearcut judgment at present. A more definitive verdict on their impact must await further research as information accumulates on the technological changes since their implementation.

The Physical Constraints to Economic Activity

There are two aspects of the physical constraints to economic activity that are particularly relevant to our discussion. The first relates to the availability and quality of materials for production processes. This aspect has been, until recently, the primary focus of analyses of natural resources adequacy. The

second relates to the properties of environmental systems in providing a set of services which support human activity. One such example is their service as receptacles for the residuals from production and consumption activities. Discussion of this problem has been associated largely with air and water pollution as examples of externalities. For the most part, economic models have separated these two aspects of the role natural endowments may play in constraining economic activity. Moreover, in many cases the discussion of pollution problems has ignored the fact that environmental systems may have a finite absorptive capacity for certain types of residuals. We are reasonably confident that in a number of cases the absorptive services of these common property resources are depletable in ways akin to those usually attributed to deposits of the materials components of our natural endowments.

Taking up the first issue now for further discussion, both of the neoclassical models described earlier have generally accepted one of two conceptions of the physical occurrence of natural resources. The first of these assumes a finite stock of the resource of homogenous quality which cannot be augmented. The second postulates that there are increasing supplies available of progressively lower grade resources.[4] One might reasonably inquire as to which view more accurately represents the availability of materials.

The second component of any forecast of the available supplies of materials is based on economic considerations. That is, the reserves of a given mineral are defined on the basis of the technical data on the availability of the element in question as well as its economic feasibility. With existing technology, implied extraction costs, and current and anticipated prices, does extraction represent an economically viable activity (i.e., yield a return on investment comparable to other alternatives)? Thus, estimates of reserves for a particular mineral potentially can be as diverse as the expectations of future price patterns. They represent one point on the long run supply curve for the element in question. Accordingly, it is difficult to judge the consequences of alternative demand projections in terms of the reserves available in a single period. Technological change and increases in demand likely will influence both the extraction costs and future prices of minerals. Both of these considerations, together with the known characteristics of ore deposits, influence estimated reserves.

In order to assess the adequacy of our materials base, it is necessary to project how the upper left-hand corner of figure 1 will change. As we have noted, this involves analysis of both the geological and the economic conditions underlying the extraction activities for a given element. Unfortunately, very little detailed analysis has been done on the components of the problem. Some research, which has received considerable attention, has attempted to forecast additional reserves as a physical relationship to the elemental composition of the earth's crust. There is no reason to believe that economic and geologic factors will behave in such a manner as to preserve a rather arbitrary statistical function relating physical measures of reserves to physical measures of the composition of the earth's crust by each element. In fact, there may be good reasons to believe such physical relationship will be quite misleading. If one believes that generally the most accessible, high-quality deposits are exploited first, then past estimates of reserves when compared with a fixed measure of the proportion of the earth's crust that includes a given element may have a considerable upward bias.

The second aspect of the physical constraints to economic activity involves the role of environmental common property resources, i.e., the role of nonpriced, freely accessible, environmental resource services. Most economic analysis of environmental pollution issues has relied on the comparative static methodology which involves an implicit assumption that a constant absorptive capacity of common property resources is available to assimilate the residuals from consumption and production activity. But scientific evidence suggests this is not appropriate. Some economic activities result in the depletion of the stock (or capacity) of common property resources that yield various life support services. The burning of fossil fuels, by consuming carbon and oxygen produces carbon dioxide, which, along with the release of fine particulates which absorb heat, hold real prospects of altering the mean global temperature with potentially catastrophic effects (Nordhaus 1977, and d'Arge and Smith). Simi-

[4] An alternative view, similar in concept to this approach, is that there is a discrete change to a "backstop technology" offering unlimited resources at low cost. This conceptualization also has enjoyed some popularity in the theoretical literature.

larly, the use of fluorocarbons associated with refrigeration, and the release of oxides of nitrogen from the practice of intensive agriculture, deplete the capacity of the ozone buffer to filter out carcinogenic solar radiations. In both cases, through altering the composition of the atmosphere, we have cases where the character and extent of human economic activity deplete common property resources which are vital constituents of our life support system.

While additional examples might be cited, the two selected serve to illustrate our point. What is at issue is whether they can be regarded as exotic exceptions to "normal" activities or a reflection of a pervasive class of external effects associated with modern industrial and extractive technology. The evidence at this stage is not clear cut, but there is increasing reason to believe that the latter may be closer to the actual state of affairs.

What has been done about incorporating effects of this sort in modeling efforts? Work along this line is meager. One effort of which we are aware is the work of d'Arge and Kogiku that investigates the implications of phenomena for the maximization of per capita utility. They modeled what was conceived as a closed economy with a fixed capacity for assimilating industrial wastes. The objective function was similar to the aggregate models cited earlier, to maximize discounted per capita utility. Utility was assumed to be strongly separable in usable outputs, and the term of the planning horizon. Their results suggested that:

> Issues emerging from environmental management arise not only from the optimal rate of waste generation in a closed medium but also with regard to the rate of extractive (or renewable) resource exploitation. If extractive resources are finite in magnitude and can for all practical purposes be exhausted, then optimal environmental management involves a 'conjunctive use' type of allocation problem where one must consider rates of extraction and rates of waste generation. Thus, the 'pure' mining problem must be coupled with the 'pure' pollution problem and questions like these become relevant which should we run out of first, air to breathe or fossil fuels to pollute the air we breathe. (p. 68)

The separability assumption for the utility function in the d'Arge-Kogiku analysis is important because the issues become more complex when it is relaxed. Vousden analyzed a related problem by considering some basic aspects of resource depletion with a nonseparable utility function to reflect a "conservation motive." The stock effect in this case plays the same role as the accumulation of pollutants in the d'Arge-Kogiku framework. The ability to reflect these factors through "shadow prices" requires that the stock effect be limited so as not to interfere with the strict concavity of the nonseparable utility function. This requirement serves implicitly to restrict the nature of the environmental transfer systems and the assimilative capacities of the natural endowments involved. Indeed, there is a growing recognition that the solution of optimal control problems of this sort with multiple state variables introduces the prospect of cyclic behavior and exerts a substantial impact on the properties of the optimal solutions given by the simpler formulations (Ryder and Heal, and Cropper).

Thus, while the greatest attention has been devoted to the implications of the nonrenewable nature of the materials components of natural resources, the available evidence suggests that the consequences of depletion of common property resources may be equally important for human welfare.

The Valuation of Economic Outputs

Can the market be relied on to take into account the interests of the future? When we consider the results of present allocation decisions associated with exhaustible natural resources that exchange on organized markets, can we be assured they will reflect fully the interest of future generations? Most economists answer these questions in the affirmative, noting, of course, that markets must be appropriately comprehensive and perfectly functioning. Stiglitz (1979) has argued that four departures from conditions required for efficient intertemporal allocations may be particularly important here and suggests a possibility for improving the efficiency of market allocations through public intervention. They include: (*a*) the structure of the market, (*b*) the absence of futures markets, (*c*) the absence of risk markets, and (*d*) the prospects for common property problems. In several of these cases, he has argued that the degree of misallocation and, hence, potential for improvement is not clear. For example, he suggested that

> Uncertainty undoubtedly has an effect on the intertemporal allocation, but for some purposes this is not

> as important as the question of what policy implication this has. . . . An appropriate question to ask, for instance, is whether a Pareto optimal improvement could be made within our market structure by taxing or subsidizing the return to holding oil. . . . The answer, in general, is no. (p. 35)

Such appraisals involve a matter of judgment and can be expected to differ among individuals confronted with the same set of "facts." By contrast, Nordhaus (1973) reviewed the same set of conditions discussed by Stiglitz and concluded that the market mechanism was an "unreliable means of pricing and allocating exhaustible appropriable natural resources" (p. 537).

A second issue arising from the reliance on private markets for the allocation of these resources (thus permitting current consumer's sovereignty, together with supply conditions, to establish their values) is that it implies an acceptance of the existing distribution of income. Here again the conventional view is that such considerations should be handled independently from the allocation of exhaustible resources. This can be accomplished through tax and transfer programs in the current period and through monetary policy for intertemporal allocations.

Nonetheless, there remains a question of what is a "fair" disposition of exhaustible resources between generations. Page (1977) recently has summarized the concerns nicely observing that

> Markets can be expected to allocate resources more or less efficiently relative to a given distribution of wealth or market power (a hypothetical ideal market would actually achieve efficiency). But markets cannot be expected to solve the problem of what is a fair or equitable distribution of wealth, either among different people at a point in time (intratemporally) or among different generations (intertemporally). The questions of depletion and generation of long-lived wastes are fundamentally questions of equitable distribution of burdens across generations. (p. 9)

What are the alternatives, and what are their implications for resource allocation? Any number have been proposed ranging from a revival of interest in Ramsey's egalitarian principles to a generalization of Rawls' max-min principle applied to intertemporal allocations (Solow 1974a). Markets will serve only to reflect the desires of the groups that can express their preferences. Recalling, of course, that such an expression requires want plus ability to pay (and, parenthetically, if future generations are deprived by the present of the wherewithal to pay, the market may not appear to them to have served their interests).

Markets, when sufficiently comprehensive and perfectly functioning, satisfy the criteria for efficient intertemporal resource allocation. The problem of registering the interests of the future in current transactions is important, as we have just noted, even when natural resources are considered to be the same as any other input. However, with the inclusion of common property resources one might well suspect that there are values and costs associated with certain resource uses which are not reflected in their market prices. Accordingly, they cannot be relied on to establish efficient resource allocations. It follows, then, that the system used to value the outputs of a neoclassical model is important for a number of reasons. Perhaps the most obvious of these arises out of considerations of intertemporal equity.

Somewhat less apparent, though of at least equal importance to evaluating the conclusions of neoclassical models, is the question of the external effects of the extraction, production, and consumption activities that use natural resources for materials inputs. Under our general definition, it might be argued that the changes in the patterns of extraction over the past three decades have increased the effective supply of the materials inputs components of natural resources while reducing the amenity and life support services of these natural resources. Thus, rather than augmenting the range of our production possibilities, we have undertaken a substitution of the use of one type of resource for another. Moreover, the reason why such substitutions become a matter of concern is that the values of the latter services are not readily reflected in market transactions that, in the main, guide decisions regarding natural resource use.

Rosenberg's 1972 description of the characteristics of the progression of technological changes in the American economy during the nineteenth and twentieth centuries as compared with earlier periods lends some support to this view. He has observed that the changes in industrial technologies can be identified with a transition from organic to inorganic sources of raw materials and that the dependency on specific sources of natural resources had been reduced. However, this transition is not without social costs. The byproduct residuals associated with the production as well

as the consumption of products based on these synthetic sources of materials inputs must be reckoned with. Indeed, there is some evidence that the ill effects of the residuals produced in association with this progression from organic to inorganic to synthetic substances has increased dramatically (Kneese and Schulze, and Page 1978). Under the broader perception of resources, these effects must be reflected in judgments as to the availability of our natural resources.

Empirical Appraisals of Resource Adequacy

As we noted at the outset, much of the recent literature on natural resource scarcity can be compared with work undertaken nearly two decades ago by Barnett and Morse when similar concerns were raised. The current answers to the importance of natural resources are structured so that the problem can be resolved in terms of a one-sector growth model. In this setting the needs for natural resources depend entirely on their role in the aggregate production function and on how that function feasibly can change with the passage of time. In a more general context we must inquire as to the role of natural resources in the relationships involving the means society utilizes to achieve its desired ends. With insufficient means to satisfy all of society's ends, we must distribute the "deficiency," i.e., allocate the scarce resources among these competing ends. But the substance of the resource rationing problem depends on the purposes to which society subscribes, as well as the resource endowments and the state of the mastery of techniques to convert the natural resources into final utility-satisfying outcomes.

At a general level, it is possible to distinguish two approaches to the problems of measuring resource scarcity. The first of these, which we shall designate as the structural method, requires investigation of the role of each of the production technologies for important goods and services as well as an evaluation of the characteristics of consumer demands for these final goods. This approach would attempt to provide an appraisal of the role of natural resources—directly and indirectly—in all production and consumption activities. It requires full documentation of the structure of supply and demand for the goods and services consumed by society. The second approach is based on the premise that we need only look at the outcomes of these decision processes in order to judge whether or not natural resources are important to economic well-being. This method is the strategy selected by Barnett and Morse. It requires that indexes be developed to signal the adequacy of natural resources. In order to appraise alternative scarcity measures it is reasonable to ask what properties an ideal scarcity index should have. One definition, proposed by A. C. Fisher is gaining wide acceptance and requires that "a measure of a resource's scarcity should have just one essential property: it should summarize the sacrifices, direct *and indirect,* made to obtain a unit of the resource" (p. 5). The original Barnett-Morse study began its analysis focusing on the classical concepts of scarcity and sought a measure independent of "values." Scarcity measures, under this view, must evaluate the real resources necessary to extract a unit of material output and should not be influenced by the differential opportunity costs associated with alternative uses of such resource inputs. Barnett and Morse proposed two measures (but noted a preference for the first): (*a*) an index of "real unit costs" and (*b*) the relative prices of extractive to nonextractive outputs.

There has been considerable debate over what is the "best" index of scarcity, whether a cost-based, rent-based, or final price-based index (see Brown and Field, A. C. Fisher, and Smith 1978). We would argue that the choice between rental measures and relative prices depends on what is to be evaluated as scarce. To judge scarcity of resources in the ground through the price of the extractive industries' outputs would not be appropriate. Rent is the better measure. However, in the case of the extracted outputs, price must be used.

Unfortunately, this is not the end of the story on the measurement of relative scarcity. We have ignored the special features of the extractive sector that would lead to further modifications in these results, because the intention was to illustrate the problems associated with measuring scarcity of extractive outputs in several simple frameworks. One cannot ignore the effects of institutional factors affecting allocation decisions. For example, the tax treatment of extractive outputs will affect the extent to which both indexes of resource scarcity actually reflects changes in the real rates of exchange for the resources involved. Changes in tax laws governing min-

erals have a long and involved history (see Page 1977 for some discussion of these issues), making it difficult, if not impossible, to separate the institutional effects from those more closely related to conditions governing availability. For example, favorable tax treatment (i.e., depletion allowances and the expensing of intangible costs) can be expected to reduce prices for minerals outputs. Alternatively, price supports for agricultural commodities, demand pro-rationing, and the mandatory oil import quota system for petroleum can be expected to increase prices.

Because such influences are present in many markets in the United States, and because their existence alone would not be sufficient to dismiss any efforts to measure relative scarcity, it becomes necessary to appraise their potential effects on the observed prices at a moment in time and the pattern of change in these prices with the passage of time. Here again, the information is limited, but what evidence there is indicates the problems introduced by differential taxes and subsidies across sectors must be given serious consideration (see Brannon).

One final technical issue arises with measurement as with modeling; that is, aggregation affects our ability to evaluate the implications of any change in the index. The movement in an index can be the result of changes in the real rates of exchange or from changes in the composition of goods involved in the index over time. Clearly this issue is not a new one and plagues any attempt to evaluate price movements at an aggregate level. While Barnett and Morse did examine alternative base years for their weighting system without apparent effects on their findings, this problem is more fundamental and concerns not only the stability of the constructed indexes but also their interpretation.

Barnett's 1979 updated analysis of the Barnett-Morse real unit cost and relative price trends in the United States and in selected other countries using both aggregate and disaggregated data does not offer any reasons to consider amending the conclusions expressed in *Scarcity and Growth.* That is, on the basis of the evidence presented, there does not appear to be a growing scarcity in supply of primary commodities. Moreover, if one accepts his arguments concerning our ability to treat environmental quality issues separately from those associated with scarcity of natural resource commodities, then little has changed since the publication of the earlier Barnett-Morse study.

However, this view may overlook some important issues associated with the statistical analysis of these data. The maintained hypothesis underlying the statistical trend analysis is that there is either no constant association or a constant negative association between the relative prices of extractive outputs and time. If the regression analysis indicates an insignificant relation or one that is statistically significant with a negative trend coefficient, then the implication is that the increasing relative resource scarcity hypothesis can be rejected. Unfortunately, given the time spans involved as well as the factors noted in the previous section of this paper, yet another plausible explanation of the behavior patterns for relative prices is possible which would invalidate the testing procedure itself. That is, there may be no constant association between relative prices and time. The relationship may well vary from subperiod to subperiod within a given sample. Without prior knowledge of these periods, it is difficult to apply conventional methods of hypothesis testing. Smith's 1978 analysis of Manthy's updated Potter-Christy data (those used in the original Barnett-Morse study) indicates that there appears to be considerable instability in such simple trend models when used with the indexes of extractive sector prices relative to the wholesale price index over the period 1900–73. Accordingly, the rejection of the increasing natural resource scarcity hypothesis based on the results of simple statistical tests using these data alone must be viewed as unsubstantiated. We should be clear on this point. Smith's evidence does not necessarily indicate that materials are growing increasingly more scarce. Rather, it suggests that one cannot rely on simple trend analysis with relative price data for the aggregate components of the extractive sector output alone to provide a reliable answer.

Implications

This paper has questioned the conventional methods for modeling the role of natural resources in economic activity. Beginning with the definition of natural resources and following on to their treatment in economic models, we have argued that there are substantive reasons for questioning both the role assigned to

natural resources and the corresponding methods for appraising their availability.

Natural resources are all the original endowments of the earth and, thus, in a general sense must be considered to be all of the resources comprising the life support system. Past theoretical and empirical studies have considered only industrial raw materials using arguably challengeable assumptions and, in so doing, implicitly ignored the role of the services of environmental common property resources that are used in economic activity. This use may take the form of serving as receptacles for the residuals from production or consumption activities or in providing hospitable environments for living organisms. In many cases, economic activities will usurp one or more of these services that are available without market exchanges. Thus, for analytical purposes, we have argued that many common property resources should be analyzed as though they were depletable, or renewable but with maximum capacities. Such a reformulation identifies the difficulties with either implicitly treating the environmental effects of production and consumption activities as separable or assuming the resources regenerate themselves in each period (i.e., ignoring the cumulative depletion associated with specific carrying capacity constraints). The conjunctive reasoning called for by d'Arge and Kogiku seems an essential first step in analyzing the role and adequacy of our existing natural resources.

The implications of such a redirection of analysis are far-reaching: they range from considerations of public policy decisions involving natural resource commodities and environmental resources to the modeling and measurement of the production technology and its change over time. They also involve the need to recognize the interdependence between economics and the natural sciences, because it is on the latter that economists will have to depend for information which the market does not readily provide.

[*Received August 1978; revision accepted March 1979.*]

References

Barnett, H. J. "Scarcity and Growth Revisited." *Scarcity and Growth Reconsidered,* ed. V. K. Smith. Baltimore, Md.: Johns Hopkins University Press, 1979.

Barnett, H. J., and C. Morse. *Scarcity and Growth: The Economics of Natural Resource Availability.* Baltimore, Md.: Johns Hopkins University Press, 1963.

Brannon, G. M. "Existing Tax Differentials and Subsidies Relating to the Energy Industries." *Studies in Energy Tax Policy,* ed. G. M. Brannon. Cambridge, Mass.: Ballinger Publishing Co., 1975.

Brobst, D. A. "Fundamental Concepts for the Analysis of Resource Availability." *Scarcity and Growth Reconsidered,* ed. V. K. Smith. Baltimore, Md.: Johns Hopkins University Press, 1979.

Brown, G. M., Jr., and B. Field. "The Adequacy of Measures for Signalling the Scarcity of Natural Resources." *Scarcity and Growth Reconsidered,* ed. V. K. Smith. Baltimore, Md.: Johns Hopkins University Press, 1979.

Burness, H. S. "On the Taxation of Nonreplenishable Natural Resources." *J. Environ. Econ. and Manage.* 3(1976):289–311.

Cropper, M. "Regulating Activities with Catastrophic Environmental Effects." *J. Environ. Econ. and Manage.* 3(1976):1–15.

Cummings, R., and W. D. Schulze. "Ramsey, Resources, and the Conservation of Mass-Energy." Paper presented at Conference on Natural Resource Pricing, Trail Lake, Wyoming, 15–17 Aug. 1977.

d'Arge, R. C., and K. C. Kogiku. "Economic Growth and the Environment." *Rev. Econ. Stud.* 40(1973):61–78.

d'Arge, R. C., and V. K. Smith. "Managing an Uncertain Natural Environment: The Stratosphere." Prepared for U.S. Environmental Protection Agency and University of Maryland Conference on Ozone Management, 16–20 July 1978.

Dasgupta, P. "Resource Depletion, Research and Development and the Social Rate of Discount." Washington, D.C.: Resources for the Future Conference on Energy Planning and the Social Rate of Discount, 3–4 Mar. 1977.

Dasgupta, P., and G. M. Heal. "The Optimal Depletion of Exhaustible Resources." *Rev. Econ. Stud.* Symposium on the Economics of Exhaustible Resources (1974):3–28.

Fisher, A. C. "On Measures of Natural Resource Scarcity." *Scarcity and Growth Reconsidered,* ed. V. K. Smith. Baltimore, Md.: Johns Hopkins University Press, 1979.

Fisher, F. M. "The Existence of Aggregate Production Functions." *Econometrica* 37(1969):553–77.

———. "Aggregate Production Functions and the Explanation of Wages: A Simulation Experiment." *Rev. Econ. and Statist.* 53(1971):305–25.

Fisher, F. M., R. M. Solow, and J. M. Kearl. "Aggregate Production Functions: Some CES Experiments." *Rev. Econ. Stud.* 44(1977):305–20.

Gilbert, R. "Optimal Depletion of an Uncertain Stock." Institute for Mathematical Studies in the Social Sciences, Stanford University, No. 207, 1976.

Goeller, H. E., and A. M. Weinberg. "The Age of Substitutability." *Science* 191(1976):683–89.

Harris, D. P., and B. J. Skinner. "The Assessment of Long-Term Supplies of Minerals." Paper presented

at RFF/NSF Conference on the Implications of Resource and Environmental Constraints on Economic Growth, San Francisco, 12–13 Feb. 1979.

Heal, G. "Economic Aspects of Natural Resource Depletion." *The Economics of Natural Resource Depletion,* ed. D. W. Pearce, pp. 118–39. New York: John Wiley & Sons, 1975.

Herfindahl, O. C. "Can Increasing Demands on Resources Be Met?" *Resource Economics: Selected Works of Orris C. Herfindahl,* ed. D. B. Brooks, pp. 274–83. Baltimore, Md.: Johns Hopkins University Press, 1974.

Hotelling, H. "The Economics of Exhaustible Resources." *J. Polit. Econ.* 39(1931):137–75.

Houthakker, H. S. "The Pareto Distribution and the Cobb-Douglas Production Function in Activity Analysis." *Rev. Econ. Stud.* 23(1955–1956):27–31.

———. *The Economics of Nonrenewable Resources.* Harvard University Res. Inst. Pap. No. 493, 1976.

Johansen, L. *Production Functions.* Amsterdam: North-Holland Publishing Co., 1972.

Kamien, M. I., and N. L. Schwartz. "The Optimal Resource Capital Ratio and Market Structure." Disc. Pap. No. 233, Center for Mathematical Studies in Economics and Management Science, Northwestern University, Aug. 1976.

———. "A Note on Resource Usage and Market Structure." *J. Econ. Theory* 15(1977):394–97.

Kneese, A. V., and W. D. Schulze. "Environment, Health and Economics—The Case of Cancer." *Amer. Econ. Rev. Proceedings* 67(1977):326–32.

Kopp, R. J., and V. K. Smith. "The Perceived Role of Materials in Neoclassical Models of the Production Technology." Paper presented at RFF/NSF Conference on the Implications of Resource and Environmental Constraints on Economic Growth, San Francisco, 12–13 Feb. 1979.

Landsberg, H. H., L. L. Fischman, and J. L. Fisher. *Resources in America's Future.* Baltimore, Md.: Johns Hopkins University Press, 1963.

Lau, L. J. "On the Measurement of Raw Materials Inputs." Paper presented at RFF/NSF Conference on the Implications of Resource and Environmental Constraints on Economic Growth, San Francisco, 12–13 Feb. 1979.

Levhari, D. "A Note on Houthakker's Aggregate Production Function in a Multifirm Industry." *Econometrica* 36(1968):151–54.

Magat, W. A. "Pollution Control and Technological Advance: A Dynamic Model of the Firm." *J. Environ. Econ. and Manage.* 5(1978):1–25.

Manthy, R. S. *Natural Resource Commodities: A Century of Statistics.* Baltimore, Md.: Johns Hopkins University Press, 1978.

Marsden, J., D. Pingry, and A. Whinston. "Engineering Foundations of Production Functions." *J. Econ. Theory* 9(1974):124–40.

Morse, C. "Depletion, Exhaustibility and Conservation." *Economics of the Mineral Industries,* ed. W. A. Vogley. New York: Amer. Inst. Mining, Metallurgical and Petroleum Eng., 1976.

Nadiri, M. I. "Some Approaches to the Theory and Measurement of Total Factor Productivity." *J. Econ. Lit.* 8(1970):1137–77.

Nordhaus, W. D. "The Allocation of Energy Resources." *Brookings Pap. on Econ. Activity* 3(1973):529–70.

———. "Economic Growth and Climate: The Carbon Dioxide Problem." *Amer. Econ. Rev. Proceedings* 67(1977):341–46.

Page, R. T. *Conservation and Economic Efficiency.* Baltimore, Md.: Johns Hopkins University Press, 1977.

Page, T. "A Generic View of Toxic Chemicals and Similar Risks." *Ecology Law Quart.* no. 2(1978):207–44.

Petersen, F. M., and A. C. Fisher. "The Exploitation of Renewable and Nonrenewable Natural Resources." *Econ. J.* 85(1977):681–721.

Potter, N., and F. T. Christy, Jr. *Trends in Natural Resource Commodities (1870–1957).* Baltimore, Md.: Johns Hopkins University Press, 1962.

Ramsey, F. "A Mathematical Theory of Saving." *Econ. J.* 38(1928):543–59.

Rawls, J. *A Theory of Justice.* Cambridge, Mass.: Harvard University Press, 1971.

Rosenberg, N. *Technology and American Economic Growth.* New York: Harper & Row, Publishers, 1972.

Ruttan, V. W. "Technology and the Environment." *Amer. J. Agr. Econ.* 53(1971):707–17.

Ryder, H. E., Jr., and G. M. Heal. "Optimum Growth with Intertemporally Dependent Preferences." *Rev. Econ. Stud.* 40(1973):1–32.

Sato, K. *Production Functions and Aggregation.* Amsterdam: North-Holland Publishing Co., 1975.

Sandler, T., and V. K. Smith. "Intertemporal and Intergenerational Pareto Efficiency." *J. Environ. Econ. and Manage.* 4(1976):151–59.

———. "Intertemporal and Intergenerational Pareto Efficiency Revisited." *J. Environ. Econ. and Manage.* 2(1977):252–57.

Schultz, T. W. "The Declining Economic Importance of Agricultural Land." *Econ. J.* 61(1951):725–40.

Schulze, W. D. "The Optimal Use of Non-Renewable Resources: The Theory of Extraction." *J. Environ. Econ. and Manage.* 1(1974):53–73.

Scott, A. "The Development of the Extractive Industries." *Can. J. Econ. and Polit. Sci.* 28(1962):70–87.

Smith, V. K. "The Implications of Common Property Resources for Technical Change." *Europe. Econ. Rev.* 3(1972):469–79.

———. "Measuring Natural Resource Scarcity: Theory and Practice." *J. Environ. Econ. and Manage.* 5(1978):150–71.

Solow, R. M. "Intergenerational Equity and Exhaustible Resources." *Rev. Econ. Stud.* Syposium on the Economics of Exhaustible Resources, 1974a, pp. 29–46.

———. "The Economics of Resources or the Resources of Economics." *Amer. Econ. Rev.* 64(1974b):1–14.

Stiglitz, J. "Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths." *Rev. Econ. Stud.* Symposium on the Economics of Exhaustible Resources, 1974a, pp. 123–37.

———. "Growth with Exhaustible Natural Resources:

The Competitive Economy." *Rev. Econ. Stud.* Symposium on the Economics of Exhaustible Resources, 1974b, pp. 139–52.

———. "Monopoly and the Rate of Extraction of Exhaustible Resources." *Amer. Econ. Rev.* 66(1976):655–61.

———. "A Neoclassical Analysis of the Economics of Natural Resources." *Scarcity and Growth Reconsidered*, ed. V. K. Smith. Baltimore, Md.: Johns Hopkins University Press, 1979.

Vousden, N. "Basic Theoretical Issues of Resource Depletion." *J. Econ. Theory* 6(1973):126–43.

State-Financed Property Tax Relief

Fred C. White

As a result of widespread dissatisfaction with rising property tax burdens, state governments are being called on increasingly to provide property tax relief. Numerous tax reform proposals are being considered by the various states. The purpose of this paper is to develop an analytical framework for evaluating the potential impacts of alternative approaches to property tax relief. Applicability of the fiscal model is demonstrated using three alternative tax relief proposals—increased state funding of elementary and secondary education, revenue transfers for a general reduction in property taxes, and a circuit breaker to ease excessive property tax burdens.

Key words: fiscal instability, property tax, tax progressivity and regressivity, tax relief

In the past two decades there has been a remarkable surge in property tax relief programs. Most of these programs involved differential assessment approaches which valued land for tax purposes according to its present use rather than its actual market value, thus reducing property tax burdens for owners of farmland and open space. Reasons for differential assessment included a feeling that property taxes unduly discriminated against farmers and a desire to preserve farmland and open space (Hady and Sibold). In most cases, the costs of these programs were borne by local taxpayers. Those taxpayers who did not qualify for preferential treatment had to pay higher taxes. With the wide disparity in wealth, income, and nonfarm real estate among local tax districts, further inequities were often created in an attempt to reduce inequitabe tax burdens on farmers.

As evidenced by the widespread concern over the passage of "Proposition Thirteen" in California, there is presently much interest in property tax relief being financed by state governments. The reason for this proposed shift in fiscal responsibility is that revenues from state governments are drawn from many sources and from a larger tax base. Proposals for state governments to reduce property tax burdens directly are taking a number of forms. The first approach involves revenue transfers designed specifically to reduce local property taxes. The revenue transfer could be in the form of either a direct payment to taxpayers in proportion to their property tax liabilities or an intergovernmental transfer to local governments with a provision that property taxes be reduced accordingly. Second, state governments can assume additional costs of financing local education. Because a large portion of the property tax is used to finance elementary and secondary education, property tax reform may be linked directly to school finance reform. A third form of property tax relief is the circuit breaker, which has been the most rapidly growing form of property tax relief for the past decade. The circuit breaker gives an income tax credit or rebate to those taxpayers with the greatest tax burden relative to their income ability-to-pay.

Although the economic and public finance literature on state government financing of property tax relief programs is expanding, several important questions remain unanswered. What state taxes should be used to finance property tax relief? Some studies have considered a proportionate increase in all state taxes (e.g., Raymond). However, considering such issues as tax regressivity, growth in revenue, and instability, it appears that the type of relief program chosen may have an effect on the financing method to be used. What criteria should be used in selecting among property tax relief programs? Most of the literature has singled out a particular form of property tax relief program, making it difficult to compare the strengths and weaknesses of the various programs. Certainly, no systematic approach has been used to analyze the different property tax relief programs. Prominent examples of circuit-breaker analyses include works by

Fred C. White is an associate professor in the Department of Agricultural Economics, University of Georgia.

Aaron, Bendick, Cook and Quindry, and Lochner and Kim. For analyses on school finance reform see Cooper, Hight, and Michelson.

The fact that various states are considering a wide variety of property tax relief measures indicates that more emphasis should be given to identification of better means for evaluating the potential impacts of these alternative approaches. The overall objective of this paper is to develop an analytical framework to be used in evaluating state-financed property tax relief programs. Application of the model will be demonstrated with empirical examples for the state government of Georgia. Emphasis is centered on a comparison of the expected impacts of three proposed approaches. Finally, consideration is given to some important implications of these results for public finance and for agriculture in particular, because the agricultural sector is a major beneficiary of property tax relief.

Conceptual Framework

Numerous attempts have been made to establish guides for tax policies. Adam Smith in the famous "canons of taxation" made perhaps the greatest contribution to this theme. As a result of these efforts, several criteria have been developed and are widely used to appraise the quality of a tax system. First, there are several criteria concerning the fiscal budget directly that are quite evident to state governments. These criteria include the level and stability of revenue, as well as such factors as ease of administration and low cost of administration and compliance. The second broad category of criteria which can be applied in judging tax systems is concerned with adjustments in the allocations of resources and adjustments in the distribution of income and wealth. The following discussion will elaborate on these concepts.

Perhaps one of the most important criteria to be used as a guide for tax policies is the adequacy criterion (Wilford, p.104). Adequacy of tax revenue involves stability of revenue in periods of recession but also growth in revenue to finance increases in government goods and services demanded by an increasing society. These two goals are clearly in conflict as the growth criterion requires that tax revenues be responsive to changes in income, while the stability criterion requires that they be unresponsive to an economic slowdown which is also measured by changes in income.

Public finance literature first described a stable tax system for state and local governments as one that would sustain a given volume and quality of governmental services throughout the various phases of a business cycle (Groves and Kahn, pp. 87–88). However, this approach failed to account for the importance of growth in tax revenue to finance the increases in public services that have occurred. More recently, fiscal instability has been viewed as fluctuation in budgetary cash flows in response to the business cycle (White and Musser, p. 2). Fiscal problems, from this viewpoint, are characterized as cash surpluses during economic booms and cash deficits during recessions. These cyclical fluctuations in fiscal conditions could result conceptually either from cyclical behavior of a single major budgetary component or several of them—tax revenues, intergovernmental transfers, expenditures, debt, or stabilization reserves.

Long-run and short-run income elasticities have been used to quantify growth and stability, respectively (Williams et al.). Corporate and individual income taxes are generally classified as having high long-run and short-run income elasticities, general sales as having medium income elasticities, and excise and property taxes as having low income elasticities (Groves and Kahn, Wilford, Williams et al.). As income taxes account for a larger proportion of total tax revenues and property taxes account for a smaller proportion, aggregate state and local taxes experience more rapid growth but are also more susceptible to short-run economic fluctuations.

The revenue-expenditure process of government has broad social and economic effects, often beyond the immediate objective of satisfying public wants (Musgrave, p. 17). These policies also affect economic efficiency through a vast array of individual choices—between work and leisure, consumption and saving, one kind of consumption good or financial asset and another (Break, pp. 179–237). Tax and expenditure programs which are used to promote economic objectives may not distribute tax burdens fairly, according to either ability-to-pay or benefits-received principles.

The general theoretical framework for incidence analysis is focused on how the burdens of different taxes are distributed vertically, according to family income. Tax incidence, as distinguished from tax impact, is the point

where the final burden of the tax rests. If part of the tax burden ultimately rests at a point other than where it initially fell, tax shifting has occurred. This shifting takes place through the interaction of supply and demand (Herber, pp. 402–27).

Adjustments in the distribution of income, resulting from changes in tax and expenditure policies, can be measured by examining tax burdens among income groups. Empirical estimates of tax burdens among income groups should take tax incidence and not just tax impact into account. Tax shifting and incidence are usually measured in a partial equilibrium sense in terms of changes in selling prices for economic goods and purchase prices for resources. A higher selling price for economic goods indicates forward shifting of the tax to the consumer, while a lower price for a factor of production indicates that the tax burden has been shifted backwards to the owners of the factors of production.

Tax incidence analysis initially makes a distinction in household income according to its source and use. Then tax burdens can be estimated according to whether the tax is shifted forward, shifted backwards, or borne directly by the person paying the tax with no tax shifting. Opinions on the incidence of the corporation income tax range from complete shifting to shareholders, on the one extreme, to forward shifting to consumers on the other. The true corporate tax incidence pattern probably contains a mixture with tax burdens on owners of capital and on consumers. Sales and use taxes generally are considered to be shifted forward to consumers. The personal income tax is borne primarily by those persons paying the tax with little shifting to other income groups. Families with different levels of income derive their income, in general, from different sources. For example, wages and salaries represent a larger proportion of total income for low income earners, while business and property income is relatively more important for high income earners. A tax on wages and salaries would, therefore, be more regressive than one on business and property income. On the uses-of-income side of household budgets, taxes that fall on consumers are generally regressive.

Methodology

To analyze systematically a fiscal system, there are several concepts that must be defined in such a manner that they can be measured quantitatively. Such concepts for progressivity, regressivity, instability, and growth are discussed in this section.

Progressivity and Regressivity

Income has been used predominantly as an indicator of taxpaying ability. A tax is said to be progressive if the amount of taxes paid as a percentage of income increases as income increases or regressive if the amount of taxes paid as a percentage of income decreases as income increases. The degree of progressivity (or regressivity), therefore, can be measured by the slope of the curve depicting tax liability as a percentage of income or $\Delta TL/\Delta I$. Because the slope of this curve can vary with the amount of revenue generated, the curves are standardized so that each tax would generate one million dollars in tax revenue.[1] A further complication arises as an individual tax may be more regressive or progressive over some income ranges than others. An overall measure of regressiveness or progressiveness can be calculated as the weighted average slope of this curve over all income categories, where the weights are determined by the number of taxpayers in each category. The weighted average unit index of tax neutrality (η) for a particular point in time is given as

$$(1) \qquad \eta = \sum_{j=1}^{c-1} W_j \frac{\Delta TL_j}{\Delta I_j},$$

where TL is average tax liability per thousand dollars of income, I is average personal income in thousand dollars, c is the number of income classes, j is the income class (for example, $j = 1$ when the income class is under three thousand dollars), and W_j is the weight based on the number of taxpayers in classes j and $j + 1$. If the value of the unit index for a particular tax is negative, then the tax is regressive. If the value is positive, the tax is progressive. Having calculated the unit index for each tax, the overall index of tax neutrality (η_T) for a particular tax structure is given by

$$(2) \qquad \eta_T = \sum_{i=1}^{m} R_i \eta_i,$$

where η_T is the index of tax neutrality for the total tax structure, η_i is the unit index of tax

[1] An increase in the tax rate would result in a proportionate increase in the slope of the curve depicting tax liability as a percentage of income.

neutrality for the ith tax, and R_i is the level of revenue generated by the ith tax. The sign of η_T indicates whether the overall tax structure is progressive or regressive.

Fiscal Instability

Several approaches could be used in analyzing budgetary instability. The first approach might be to concentrate on tax instability. Governments may be interested in the possibility of actual revenues being less than their targets. This would suggest that revenue deviations below the target should be treated differently than those above. In the portfolio literature this has been handled by using semivariance measures that ignore deviations above target levels (Markowitz 1959). Similarly, tax instability could be introduced in a policy-making model as a safety-first rule. With this rule, selection of tax structures would depend on the security of generating a specified level of revenue in order to finance selected expenditure programs. A major shortcoming of such approaches in dealing with fiscal instability is that expenditures, as well as revenues, may fluctuate with the business cycles. For example, public welfare, which is an increasingly important component of state government finance, is countercyclical. The approach used to measure fiscal instability in this analysis is an extension of the concept of portfolio selection as first reported by Harry Markowitz (1952, pp. 77–91) and further expanded by Markowitz (1959). This approach, as described below, accounts for instability in revenues and expenditures.

Instability associated with the cash flow of a particular revenue or expenditure category can be measured by the standard deviation. Similar to the index of tax neutrality, the standard deviation is calculated on a per unit basis—the standard deviation per million dollars of revenue or expenditure.

This concept of instability applies only to a single budgetary category and must be extended to measure fiscal instability for a budget that includes several revenue and expenditure categories. When financing a specified combination of expenditure programs, it may be possible to diversify away fiscal instability through the selection of a combination of taxes that will generate a given level of revenue and minimize the level of instability.

The concept of diversification relates to the correlation that exists between budgetary cash flows. If two taxes are positively correlated, the movement in the level of revenue generated by these taxes would correspond throughout the business cycle. If the two taxes were correlated negatively, then an increase in the revenue from one tax would occur while revenue from the other tax would show a decrease. To diversify away instability, the tax structure would have to contain taxes that were not perfectly correlated, i.e., the movement in tax revenue would not be in exactly the same direction and proportion. The concept of diversification can be extended to expenditures, which also exhibit instability. For example, welfare expenditures are highest during recessions when tax revenues are lowest. Therefore, appropriate diversification measures for a particular government will be dependent on the level and instability of its expenditure programs, as well as its tax structure.

To determine fiscal instability for an entire budget including several revenue and expenditure categories, we need to know the unit standard deviation for each cash flow, the correlation between cash flows, and the level of each cash flow. Expenditures, which represent a cash outflow rather than a cash inflow, can be considered as a negative revenue. The overall measure of fiscal instability can be expressed as

$$\sigma_T^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} R_i R_j \rho_{ij} \sigma_i \sigma_j, \tag{3}$$

where σ_T^2 is the overall variance of budgetary cash flows, R_i is the level of cash flow from the ith budgetary category (revenue or expenditure), ρ_{ij} is the correlation coefficient between the ith and jth budgetary categories (expenditures are considered negative revenues when calculating ρ coefficients), σ_i is the unit standard deviation for the ith budgetary category, and n is the number of budgetary categories.

Growth Rate

The measure of overall growth for a particular tax structure is defined as a weighted average of growth rates for each individual tax considered.

$$\gamma_T = \frac{\sum_{i=1}^{n} \gamma_i R_i}{R_T}, \tag{4}$$

where γ_T is the projected overall growth rate,

R_T is total tax revenue, γ_i is the projected growth rate for the ith tax, R_i is revenue generated from the ith tax, and n is the number of tax categories. The growth rate for the ith tax (γ_i) is weighted according to R_i/R_T, the percentage of total revenue generated by the ith tax. If the tax structure contains several taxes, the overall growth rate is a weighted average of the growth rates of the individual taxes. Therefore, given the growth rates of the individual taxes, the overall growth rate of the tax structure depends upon the amount of revenue produced by each tax.

The Fiscal Model

Although tax neutrality, fiscal instability, and growth concepts discussed above provide an intuitive basis for choosing between two taxes, a systematic approach is required to analyze a complete tax structure. By varying the level of individual taxes, it is possible to develop a large number of tax structures, and each tax structure will have associated with it a specific level of tax neutrality, instability, and expected growth rate. The set of possible tax structures as shown in figure 1 can be termed the attainable set. Those tax structures with an overall index of neutrality greater than zero are considered progressive, while those with negative values are regressive. However, from the potential set of all possible tax structures that can be constructed, we are most interested in those tax structures that define the efficient frontier (curve *ABCD* in figure 1). For a given growth rate, an efficient tax structure provides the lowest possible degree of tax instability for any level of tax neutrality. Any

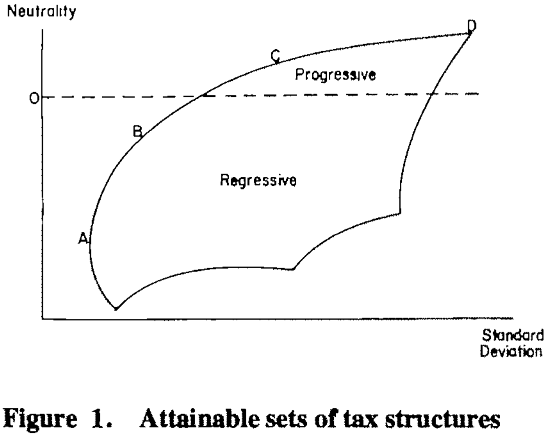


Figure 1. Attainable sets of tax structures

possible tax structures that are not on the frontier are inefficient, because for any level of neutrality these tax structures provide less stability than those tax structures on the efficient frontier.

Quadratic programming is used to develop the set of feasible tax structures having the property that variance σ_T^2 is minimum for associated level of tax neutrality η_T.[2] The quadratic programming model can be defined as follows:

$$(5) \quad \text{Minimize } \sigma_T^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} R_i R_j \rho_{ij} \sigma_i \sigma_j,$$

such that

$$(6) \quad \sum_{i=1}^{n} \eta_i = \lambda (\lambda = 0 \text{ to unbounded}), \text{ and}$$

$$(7) \quad \sum_{i=1}^{n} R_i = R_T,$$

$$(8) \quad \sum_{i=1}^{n} \frac{\gamma_i}{R_T} R_i \geq \gamma_T,$$

$$(9) \quad R_k \leq UL_k \text{ (for all } k, k = 1 \text{ to } m),$$

$$(10) \quad R_i \geq LL_k \text{ (for all } i, i = 1 \text{ to } m),$$

where R_i is the level of cash flow from the ith budgetary category (revenue or expenditure), γ_i is the expected annual growth rate of the ith tax, σ_i is the standard deviation of the ith budgetary cash flow, ρ_{ij} is the correlation between the ith and jth cash flow, UL_k is the upper limit on the kth tax, LL_k is the lower limit on the kth tax or expenditure, n is the number of budgetary cash flows, and λ is a scalar.

The summation term in equation (5) is the variance and the summation term in equation (6) is the aggregate index of tax neutrality. Parameterizing λ produces a sequence of solutions of increasing tax progressivity (or declining tax regressivity) and fiscal instability. The final solution in this sequence represents the maximum level of tax progressivity that can be achieved with the specified constraints. Solutions are obtained for critical turning points, such that for the current overall index of neutrality η_T, determined by λ, the variance σ_T^2 is minimum. These solutions are sufficient to determine the efficient frontier.

---

[2] The quadratic programming model developed in this paper is an adaptation of the standard quadratic portfolio selection model developed by Freund (pp. 253–63).

Estimation Results

Concepts of tax neutrality, growth, and fiscal instability developed in this paper are estimated empirically with budgetary data for the Georgia state government. Major own sources of revenue for the state government of Georgia, in order of importance, are taxes on sales, personal income, motor fuel, corporation income, alcoholic beverages, tobacco, and motor vehicles. The empirical estimates developed in this section will be applied in the next section using the state government fiscal model.

Measurement of Growth and Instability

A major distinction between growth and instability in tax revenue is that growth is a long-run phenomenon, while instability refers to short-run behavior (Williams et al., p. 268). The reason for this distinction is that most state and local government expenditures are budgeted through the legislative process several months before actual revenues are known. Policy makers usually base expenditure decisions on "typical" growth patterns in tax revenue. Therefore, state and local government finance is based on predictable and steady growth over time. Fiscal instability can be measured by the degree to which actual values of budgetary cash flows (revenues and expenditures) differ from predicted values.

It is possible to measure both growth and fiscal instability from a single regression equation. Such an equation would be formulated to measure growth in a budgetary cash flow over time. An important factor to take into consideration in this formulation is that tax rates and rate structures also affect tax revenue. One approach that can be used to account for changes in tax rates is to adjust the revenue data for such changes. This approach assumes that a given percentage change in tax rate results in a proportionate change in tax revenue; i.e., the rate-revenue elasticity is assumed to equal one. An alternative procedure, which is used in this study, allows the rate-revenue elasticity to be determined by the data. The growth path is determined from the following equation:

$$R_{it} = at^b e^{cr_{it}}, \tag{11}$$

where R_{it} is revenue from the ith tax in year t, t is the time variable indicating year, r_{it} is the tax rate for the ith tax; and a, b, and c are regression coefficients. The annual growth rate (dR/dt) is simply the regression coefficient b and instability σ is calculated from the deviations between actual and predicted revenue. The rate-revenue elasticity $(dR/dr)(r/R)$ is simply cr. Similar equations were estimated for major expenditure categories and used to estimate fiscal instability associated with these expenditures.

For the regression analysis, tax revenue and expenditure data for the period 1952–73 were obtained from U.S. Bureau of the Census, *Governmental Finances*. Tax rates were obtained from Georgia Department of Revenue, *Statistical Report*. The state government on several occasions changed the tax rate on motor fuel and tobacco. In addition, there was a major structural change in several taxes beginning in 1956. To represent this change, a dummy variable, with a value of 1 for 1952–55 and zero otherwise, was included where appropriate.

The projected growth rates from these equations were used rather than actual growth rates to abstract from the effects of short-run fluctuations in aggregate economic activity, which are accounted for in the measures of variability. Also, projected growth rates would be more useful for planning purposes. Personal income and corporation income taxes have the highest growth rates among the seven major taxes (table 1) and, also, the only growth rates above 10% annually. Growth rates on tobacco, alcoholic beverages, and sales taxes range from 7.35% to 8.10%. Motor vehicle and motor fuel taxes are the two slowest growing taxes. The overall growth rate for 1976 is 9.62%.

Table 1. Empirical Estimates of Growth, Instability, and Equity in Tax Revenue

Taxes	Unit Index of Tax Neutrality[a]	Growth Rate[b] (%	Unit Variance[c]
Motor vehicle	−0.0081	6.68	0.000771
Tobacco	−0.0198	7.35	0.007091
Alcoholic beverages	−0.0104	8.10	0.006151
Sales	−0.0156	7.50	0.000490
Personal income	0.0027	15.80	0.020148
Corporation	−0.0067	10.81	0.015132
Motor fuel	−0.0130	5.34	0.000853

[a] Index of tax neutrality per million dollars of tax.
[b] Annual increase in tax revenue projected from trend regression equations.
[c] Variance per million dollars of tax revenue.

The variability in cash flows was calculated from deviations in trend lines. The measure of variability used in the quadratic programming model is unit variance, which is the variance per million dollars of tax revenue. The unit variances for the major taxes are presented in table 1. Perhaps the easiest way to interpret one of these figures is to take its square root or standard deviation and convert it to a percentage by multiplying by 100. This calculation yields the coefficient of variation. For example, the tobacco tax has a coefficient of variation of 8.42%. A comparison of unit variances indicates the relative variability among the taxes. Ranking the taxes according to unit variances reveals that motor vehicle, motor fuel, and sales taxes are the three most stable taxes.[3] Personal income and corporation income taxes are the most unstable taxes. As indicated earlier in this paper, covariance terms between each two taxes and between each tax and each expenditure also are important in determining the overall instability of the fiscal system.

Measurement of Tax Neutrality

To determine tax burden, individual taxes had to be allocated among income categories.[4] Data used to allocate taxes among income groups were obtained from three sources: U.S. Bureau of the Census, *Census of Population;* U.S. Department of Labor, *Survey of Consumer Expenditures;* and Georgia Department of Revenue, *Statistical Reports.* It was assumed that the same relative distribution of expenditures from the *Survey of Consumer Expenditures* would hold for Georgia. Consequently, it was the relative distribution and not the absolute level of these expenditures that was used in the present study.

In general, the amount of taxes paid was positively related to family income. Personal income taxes ranged from $7 for families with less than $3,000 in income to $1,482 for families with more than $25,000 in income. Sales taxes were $115 in the lowest income category and $554 in the highest income category. Average tax payments for the total of all seven taxes were eleven times greater in the highest income category than in the lowest income category—$2,668 compared to $227. However, average income in the upper category was almost thirty times greater than income in the lowest category.

The level of taxes paid was converted to taxes paid per thousand dollars of income as a measure of tax burden. For six of the seven taxes, the highest tax burden occurs in the lowest income category and the lowest tax burden occurs in the highest income category. This inverse relationship between tax burden and income indicates that these taxes are regressive. Only the personal income tax shows a positive relationship between tax burden and income. Although the tax structure appears to be regressive, calculating the index of tax neutrality for each tax will quantify the extent to which the tax structure is regressive.

Empirical estimates of the unit index of tax neutrality, which indicates the regressiveness or progressiveness of generating one million dollars in revenue from a particular tax, are presented in table 1. Ranking the seven major taxes from most progressive to most regressive reveals that the personal income tax and the corporation income tax are the two most progressive taxes. The sales tax and tobacco tax are the most regressive taxes.

In summary, the taxes which are the fastest growing—personal income and corporation income taxes—are the most progressive. However, these taxes are also the most unstable. Other taxes, such as the sales tax, are more stable; however, these taxes are regressive and slow growing. All of these characteristics must be taken into consideration in a systematic manner to choose the appropriate tax structure.

Programming Results: Property Tax Relief

Three alternative state-financed property tax relief programs were analyzed. These programs included (*a*) revenue transfer, (*b*) increase in state educational expenditures, and (*c*) circuit breaker. A circuit-breaker program that refunded to individuals all property tax payments that exceeded 3% of adjusted gross income would cost Georgia approximately $80 million. To simplify comparisons, the cost of the other two programs were also set at $80 million.

[3] Stability is measured by the size of the unit variance. The most stable tax has the smallest unit variance.

[4] Procedures used to allocate taxes are similar to those used in Tax Foundation, *Tax Burdens and Benefits of Government Expenditures by Income Class,* 1961 and 1965 (1967, p. 11). The basis for allocation was as follows: (*a*) individual income tax–current income, (*b*) corporate income tax–half total current consumption and half dividend income, (*c*) alcoholic beverages tax–alcoholic beverage expenditures, (*d*) tobacco tax–tobacco expenditures, (*e*) motor fuel tax–motor fuel expenditures, (*f*) sales tax–consumer expenditures, and (*g*) motor vehicle tax–value of motor vehicles.

The analytical model presented in equations (5) through (10) was used to identify efficient tax structures—minimum fiscal instability for any level of tax neutrality—for the Georgia state government. The 1976 tax structure and expenditure programs were taken as given, i.e., expenditures were held constant at their 1976 levels and individual taxes could not be reduced below their 1976 levels. Growth rates for the revenue to finance the three expenditure programs were based on appropriate historical rates. Because state educational expenditures had grown at an average rate of 5.6% in recent years, taxes to finance these expenditures were assumed to grow at the same rate. Taxes to finance the circuit breaker were assumed to grow at 9.6%, the overall growth rate in taxes. Two growth rates for revenue transfers were considered: (*a*) a zero growth rate and (*b*) the historical growth rate for intergovernmental transfers from the Georgia state government to local governments (10.1%). The problem was to find how the $80 million increase in government expenditures resulting from the various property tax relief programs would be financed in an efficient manner. In defining an efficient tax structure any tax could be increased up to 100 percent above its 1976 level.

The programming results showing the efficient tax structures for financing the property tax relief programs are shown in table 2. The results are presented in a manner so that policy makers could make a choice from among tax structures with various neutrality and stability characteristics, realizing the instability is minimum for any level of tax neutrality. Although economic efficiency issues are not considered directly, the discussion and references on economic efficiency cited in the conceptual framework section should be considered in choosing among tax structures.

Under each property tax relief program, several alternative financing methods are presented in table 2. The first method reported is the most stable, while the final method is the least regressive. Financing the first revenue transfer program with the motor fuel tax would result in an overall index of neutrality of −16.06 and fiscal instability of $140.58 million. The index of tax neutrality in this case is calculated for the $80 million in motor fuel taxes plus the $1586 million in the current tax structure. The fiscal instability is calculated for the seven major taxes and five major expenditure programs, not just the $80 million in new taxes. The overall index of tax neutrality could be reduced to −14.80 by financing this revenue transfer program with the personal income tax; however, fiscal instability would be increased to $149.63 million.

From table 2, it is evident that the method of financing property tax relief should be related to the type of relief program chosen. The first revenue transfer program would be financed efficiently through motor fuel and personal income taxes or a combination of one of these taxes and motor vehicle taxes. The second revenue transfer program, having a higher growth rate, could be financed efficiently through the sales and personal income tax or the motor vehicle and personal income tax. At low levels of tax neutrality, increased educational expenditures could be financed primarily with sales taxes or a combination of sales, alcohol, and motor vehicle taxes. At more progressive levels of taxation, these expenditures could be financed with personal income taxes. The personal income tax would be used predominantly to finance the circuit breaker. Some major differences among the tax relief programs are evident. The state's fiscal system is more stable at all levels of tax neutrality with revenue transfers than with the other two programs. The circuit breaker results in the most instability.

Although the information in this table should prove helpful to policymakers, other factors also should be taken into consideration. An increase in the state's educational expenditures should help reduce inequities in educational programs. The circuit breaker will reduce the regressive nature of the property tax to a greater extent than a general property tax reduction resulting from either a revenue transfer or increase in educational expenditures. Also, the effect of the tax structure on economic efficiency will differ at the various points on the efficient frontier. For example, financing increased educational expenditures with the personal income tax will tend to reduce savings, investment, and, hence, economic growth more than a sales tax. Thus in selecting a tax relief program, policy makers must consider trade-offs in tax neutrality, stability, growth, and economic efficiency.

Further Applications

The fiscal model developed in this study also can be used to analyze other problems that

Table 2. Programming Results Showing Efficient Tax Structures to Finance Alternative Property Tax Relief Programs

Solution Number	Motor Vehicle	Tobacco	Alcohol	Sales	Personal Income	Corporate Income	Motor Fuel	Tax Neutrality	Standard Deviation
	---Million Dollars---							Index Value	Million Dollars
Revenue Transfer (0 Growth Rate)									
1	0	0	0	0	0	0	80	-16.06	140.58
2	40	0	0	0	0	0	40	-15.86	140.83
3	40	0	0	0	40	0	0	-15.24	145.28
4	0	0	0	0	80	0	0	-14.80	149.63
Revenue Transfer (Growth Rate Equals State Aid Rate)									
1	0	0	0	31	49	0	0	-15.36	146.43
2	0	0	0	31	49	0	0	-15.36	146.43
3	28	0	0	0	52	0	0	-15.10	146.60
Increased Educational Expenditures									
1	0	0	0	76	4	0	0	-16.19	144.66
2	40	0	0	32	8	0	0	-15.81	144.85
3	40	0	34	0	6	0	0	-15.68	144.99
4	40	0	0	0	15	0	25	-15.63	145.22
5	40	0	0	0	40	0	0	-15.24	148.00
6	0	0	0	0	80	0	0	-14.80	152.30
Circuit Breaker									
1	0	0	0	35	45	0	0	-15.44	149.92
2	32	0	0	0	48	0	0	-15.14	150.11
3	0	0	0	0	80	0	0	-14.80	153.55

may be of interest to policy makers. First, additional constraints could be incorporated into the model. These constraints might be concerned with problems of efficiency or economic growth. Second, new tax programs could be analyzed in this framework. A third extension might involve a different objective function.

As an example of the latter case, the model has been used to trace the trade-off between growth in tax revenue and fiscal instability, while holding the level of tax neutrality constant. These results, which are shown in table 3, indicate that the level of tax neutrality has a significant impact on the position of the efficient growth-instability frontier. These results also indicate that higher growth rates in tax revenue can be achieved only with a more unstable tax structure.

Implications

The three property tax relief programs considered in this paper have special implications for agriculture. First, the level of tax relief for agriculture would be greater with the circuit breaker than either of the other two programs. The average refund per farmer would be $580 with a circuit breaker compared with less than $75 for an equivalent revenue transfer or increase in educational expenditures. Second,

Table 3. Programming Results Showing the Trade-Off in Growth and Instability with Taxes Expressed as a Percentage of Their 1976 Levels

Solution Number	Motor Vehicle	Tobacco	Alcohol	Sales	Personal Income	Corporate Income	Motor Fuel	Growth Rate	Standard Deviation
	Percent								Million Dollars
Index of Tax Neutrality $\eta_T = -15$									
1	200.00		200.00	80.56	94.58		200.00	8.39	128.42
2	200.00		200.00	145.16	110.61			9.31	139.32
3	200.00		46.34	158.57	118.58			9.43	141.36
4			31.86	167.51	127.32			9.64	145.37
5				170.29	128.98			9.67	145.85
6		200.00		141.18	137.12			9.82	152.10
Index of Tax Neutrality $\eta_T = -10$									
1	200.00		200.00	27.61	148.25	79.84	200.00	9.69	159.37
2	200.00		200.00	31.93	154.39	40.59	200.00	9.71	159.48
3	200.00		200.00	100.21	176.56		2.48	10.64	169.48
4	200.00		200.00	101.01	176.76			10.65	169.61
5	200.00			118.46	187.13			10.81	172.12
6				126.14	195.12			11.01	176.22
7		119.82		108.69	200.00			11.10	179.90
8		200.00		94.72	200.00	20.89		11.15	182.42

tax refunds would vary inversely with farm income under the circuit breaker but remain constant under the other alternatives. Hence the circuit breaker would have a stabilizing effect on income. The tax refunds from the circuit breaker could range from no refund at high levels of net farm income to a refund as high as total property tax payments for farmers with negative net farm income.

Most property tax relief programs would result in windfall gains for current landowners. Since property taxes would be reduced, future earnings from the land would increase and, hence, its present value would increase. Of the three programs, the capitalization of a reduction in property taxes is likely to be lowest under the circuit breaker. In this case, the tax refund is linked to the owner's income and not directly to land. For example, a low income, inefficient farmer may be eligible for tax relief; but when an efficient neighbor buys the land for expansion, he would not expect to receive the same level of tax refund. Also, the farmland market generally is considered as a competitive market with prices determined on the margin by efficient producers. Because these investors would receive lower refunds than the average farmer, all of the tax reduction could not be capitalized into land values. Only the level of tax reduction for efficient producers would be capitalized under the circuit breaker.

Results from this analysis indicate that fiscal instability in state and local governments may be substantial. This instability can be attributed to two general factors: increased reliance on fast-growing but unstable taxes, such as personal income and corporation income taxes, and increased welfare expenditures. Heavy reliance on income taxes in state and local government finance is advantageous for the process of raising revenue to finance the rapidly growing public service sector. However, these taxes increase the state's susceptibility to the business cycle.

Given the level of property tax relief that the state desires to maintain, it is possible to reduce fiscal instability through the selection of

an appropriate tax structure. By considering a complete tax structure, it is possible to diversify away instability by selecting a combination of taxes that will minimize instability for any level of tax neutrality. The results from this analysis indicate that there are no clear-cut rules of thumb, such as increasing the sales tax, that can be applied to identify efficient tax structures for financing property tax relief. Instead, it is necessary to develop a complete programming model for each state. Once the efficient frontier showing the trade-off in tax neutrality and instability is developed, the policy makers can choose the tax structure that is best for the particular governmental unit under consideration.

Even those states that are constitutionally restricted to a balanced budget may face problems of fiscal instability. Whenever these states experience a decline in revenues, their expenditures must be reduced in order to avoid deficit financing. However, it may be possible to institute changes in their tax structures that would help reduce tax instability and, hence, the necessity for frequent and unplanned changes in expenditures.

[Received November 1977; revision accepted November 1978.]

References

Aaron, Henry. "What Do Circuit-Breaker Laws Accomplish?" *Property Tax Reform,* ed. George E. Peterson, Washington, D.C.: Urban Institute, 1973.

Advisory Commission on Intergovernmental Relations. *Property Tax Circuit-Breakers: Current Status and Policy Issues,* M-87. Washington, D.C., Feb. 1975.

Bendick, Marc. "Designing Circuit-Breaker Property Tax Relief." *Nat. Tax J.* 27, March 1974, pp. 19–28.

Break, George F. "The Incidence and Economic Effects of Taxation." *The Economics of Public Finance.* Washington, D.C.: The Brookings Institution, 1974.

Cook, Billy D., and Kenneth E. Quindry. "Humanization of the Property Tax for Low-Income Households." *Nat. Tax J.* 22(1969):357.

Cooper, Paul D. "State Takeover of Education Financing." *Nat. Tax J.* 24(1971):337–356.

Freund, R. J. "The Introduction of Risk into a Programming Model." *Econometrica* 24(1956):253–63.

Georgia Department of Revenue. *Statistical Report.* Atlanta, Ga., annual.

Groves, Harold M., and C. Harry Kahn. "The Stability of State and Local Tax Yields." *Amer. Econ. Rev.* 42(1952):87–102.

Hady, Thomas F., and Ann Gordon Sibold. *State Programs for the Differential Assessment of Farm and Open Space Land.* USDA ERS Econ. Rep. No. 256, Apr. 1974.

Herber, Bernard P. *Modern Public Finance, The Study of Public Sector Economics.* Homewood, Ill.: Richard D. Irwin, 1971.

Hight, Joseph E. "Full State Funding and the Distribution of Educational Resources in Hawaii." *Nat. Tax J.* 27(1974):1–8.

Lochner, Allyn O., and Han J. Kim. "Circuit Breakers on Farm-Property-Tax Overload: A Case Study." *Nat. Tax J.* 26(1973):233–40.

Markowitz, Harry. "Portfolio Selection." *J. Finance* 7(1952):77–91.

———. *Portfolio Selection: Efficient Diversification of Investments.* New York: John Wiley & Sons, 1959.

Michelson, Stephen. "Equal School Resource Allocation," *J. Human Resourc.* 7(1972):283–306.

Musgrave, Richard A. *The Theory of Public Finance,* New York: McGraw-Hill Book Co., 1959.

Raymond, George M. "The Future of the Property Tax in Education Finance." *Property Taxation and the Finance of Education,* ed. Richard W. Lindholm, pp. 113–124. Madison: University of Wisconsin Press, 1974.

Tax Foundation. *Tax Burdens and Benefits of Government Expenditures by Income Class, 1961 and 1965,* New York, 1967.

U.S. Bureau of the Census. *1970 Census of Population,* Washington, D.C., Mar. 1972.

U.S. Bureau of the Census. *Governmental Finances in 1972–73.* Washington, D.C., 1975.

U.S. Department of Labor, Bureau of Labor Statistics. *Survey of Consumer Expenditures 1972–73.* Washington, D.C., 1975.

White, Fred C., and Wesley N. Musser. "Financing State and Local Services in a Cyclical Economy." *S. J. Agr. Econ.* 8(1976):1–10.

Wilford, Walton T. "State Tax Stability Criteria and the Revenue-Income Elasticity Coefficient Reconsidered." *Nat. Tax J.* 28(1965):304–12.

Williams, William V., Robert M. Anderson, David O. Froehle, and Kaye L. Lamb. "The Stability, Growth and Stabilizing Influence of State Taxes," *Nat. Tax J.* 26(1973):267–73.

The Price and Profit Performance of Leading Food Chains

Bruce W. Marion, Willard F. Mueller, Ronald W. Cotterill, Frederick E. Geithman, and John R. Schmelzer

The net profits and grocery prices of large food chains were found to be positively and significantly related to market concentration and a chain's relative market share. The results refute the notion that higher profits for dominant firms in concentrated markets are due to efficiency and lower costs. Increased profits in noncompetitively structured markets accounted for about one-third of the increase in prices. Higher retailer costs in noncompetitive markets appear to stem from inefficiencies and cost increasing forms of competition.

Key words: competition, food retailing, industrial organization, market structure, prices.

This paper reports the results of an analysis of the relationships between the market structure in which food chains operate and their profit and price performance. The analysis was made possible because of an unusually rich body of data collected by the Joint Economic Committee (JEC) of the U.S. Congress. The then chairman of the JEC, the late Senator Hubert H. Humphrey, requested that the authors analyze these data for the committee. This paper reports the major findings of the study, including some results not included in the original analysis and clarifications of several questions raised by some reviewers of the JEC report.[1]

The Structural Setting

Between 1948 and 1975 the share of U.S. grocery store sales held by the largest twenty chains rose from 26.9% to 37.0%, despite A&P's decline from 10.7% to 4.9%. These and other chains (firms with eleven or more stores) have become the dominant institutional force in food retailing, accounting for 57% of all grocery store sales and nearly 70% of all supermarket sales.

While the level and trends of concentration at the national level indicate the potential degree of market power in procurement, the performance of food retailers as sellers is largely determined by the structure of local markets. Food retailing, unlike many industries, is highly localized and competition for customers is limited to a small geographic area.

The level of local market concentration in food retailing is significant for two reasons. First, the level of concentration within a market is likely to influence the competitive conduct and strategies of the firms operating in the market. Second, the level and trends in local market concentration may serve as a proxy for other market structure variables that are more difficult to measure. For example, high or increasing concentration suggests that barriers to entry are high or increasing, while low or decreasing concentration may indicate the reverse.

Local market concentration followed a persistent upward trend between 1954 and 1972. For a sample of 194 Standard Metropolitan Statistical Areas (SMSAs), the four largest firms in each SMSA controlled an average of

Bruce W. Marion is an agricultural economist with ESCS, USDA, and adjunct professor, University of Wisconsin. Willard F. Mueller is Vilas Research Professor of Agricultural Economics, professor of economics, and professor of law, University of Wisconsin; Ronald W. Cotterill is an assistant professor, Michigan State University; Frederick E. Geithman is project coordinator, Department of Agricultural Economics, University of Wisconsin; and John R. Schmelzer is a research assistant in the Department of Agricultural Economics, Michigan State University.

The research on which this article is based was conducted at the University of Wisconsin-Madison as part of North Central Regional Project NC-117.

[1] The original analysis appears in JEC Report (Marion et al.). For comments on the report by academic economists see JEC, pp. 185–220.

45.1% of grocery store sales in 1954 and 52.1% in 1972. The proportion of highly concentrated markets (four-firm concentration, CR_4, over 60%), rose from about 5% to 25% of the 194 SMSAs.

Analysis of Profit and Price Performance

The conceptual framework used in the study is that of industrial organization theory, which holds that the structure of a market strongly influences the conduct of the market's participants, which, in turn, largely determines market performance. There have been many empirical tests of this theory across numerous industries, using such indices of performance as progressiveness, operational efficiency, and industry profits. Although relationships found between market structure and the different performance measures are somewhat mixed, the relationship between profits and market structure has been positive in the vast majority of reputable studies. L. W. Weiss, the leading scholar in this area, recently reviewed the "massive effort" to test the economic prediction that concentrated industries will have higher margins. He concluded, "by and large the relationship holds up for Britain, Canada and Japan, as well as in the United States. In general the data have confirmed the relationship predicted by theory, even though the data are very imperfect and almost certainly biased toward a zero relationship."

The debate continues, however. Positive relationships between market structure and profits may be due either to higher prices, lower costs, or both. The welfare implications obviously differ depending upon which is true. This is the first study in which both profits and price data were available for analysis and is one of the few studies in which data allowed analysis of price levels across markets. In addition, the quality of the data was far superior to that used in most industrial organization studies.

In interpreting the statistical relationships reported here, the reader should keep in mind that the models tested attempt to explain the price and profit performance of individual firms rather than industries. Industrial organization theory is concerned primarily with the behavior of industries, i.e., the combined behavior of groups of firms. Because there is always variance in the behavior among the firms composing an industry, in studies undertaking the more difficult task of explaining the prices and profits of individual firms, it is appropriate to control for the unique characteristics of some firms.

The Data

The JEC requested quarterly sales and net profit data from seventeen large chains for the four years, 1970–73, and for the first three-quarters of 1974.[2] Fifteen of these chains had 1974 sales greater than $1 billion; all seventeen were of sufficient size to capture firm economies of scale identified by the National Commission on Food Marketing (p. 140). Data were requested for each retail grocery store operating division and for each SMSA over 500,000 in population. Company responses provided comparable data for 114 divisions of fourteen companies. Six companies also furnished sales and net profit data for their operations in fifty large SMSAs. The division and SMSA data series were analyzed separately.

The JEC also requested the chains supply price comparison checks that had been conducted during October 1974. Three large chains provided comprehensive price data for thirty-five SMSAs in which one or more operated. From these data, thirty-nine observations were calculated of the weighted average cost to consumers of a "grocery basket" comprised of ninety-four comparable grocery products.

These data were used to test the hypothesis that firm profits and prices in a market are significantly influenced by the competitive structure of that market. The variables included in the analysis and the theoretical reasons for them are discussed below.

Independent Variables

The analysis uses several variables in addition to measures of market structure. Several of these are control variables designed to adjust for factors creating measurement errors in our statistical variables; others are included to measure nonstructural differences in firms and markets that are hypothesized to influence significantly profits or prices.

[2] These chains operated more than 12,700 grocery stores during 1974, which was 52% of the total number of chain stores (excluding convenience stores). Their combined sales were $43.8 billion, which represented 69% of all chain food store sales and 37% of total food store sales.

Four-firm concentration ratio (CR_4). The four-firm concentration ratio is the sum of the market shares of the top four firms in a market. When a few sellers control most sales in a market, they tend to behave interdependently rather than as independent competitors, resulting in implicit or explicit forms of collusion to enhance profits and prices above the competitive level. Although the precise nature of the relationship between concentration and profits (prices) must be determined empirically, we expect that CR_4 will be positively related to both prices and profits. Economic theory suggests that prices and profits would not be linearly related to concentration over the entire range of concentration. Rather, a priori reasoning and several empirical studies of manufacturing industries suggest that some critical level of concentration must be reached before firms achieve sufficient interdependence in behavior to raise prices above competitive levels. Thereafter, prices would be expected to rise until perfect collusion and joint profit maximization is achieved, after which prices would level off, as illustrated in figure 1.

Building on the empirical approaches of Rhoades, Dalton, White, and others, we examined a class of S-shaped functional relationships between CR_4 and profits (prices) in addition to a simple linear relationship. This class is generated by the following nonlinear transformation of the partial relationship between concentration and profits (prices).

$$P/S = f(CCR_4, \ldots\ldots, + \epsilon),$$

where

$$CCR_4 = \beta \frac{(CR_4 + a)^3}{1 - 3(CR_4 + a) + 3(CR_4 + a)^2}$$

and

$$0 \leq CR_4 \leq 1.$$

β is a parameter estimated by linear least squares regression; (a) is a parameter which shifts the inflection of the S-curve and hence its location in concentration-profits (prices) space. The formula $I = .5 - a$ determines the inflection point (I) of the curve. For theoretical reasons, (a) was constrained to the range $-.3$ to $.2$. Figure 1 illustrates the general form of this function and its location in concentration-profit (prices) space for different values of (a). Given a limited range of CR_4 ($> .20 < .80$), the relevant portion of the S-curve for different values of (a) is indicated

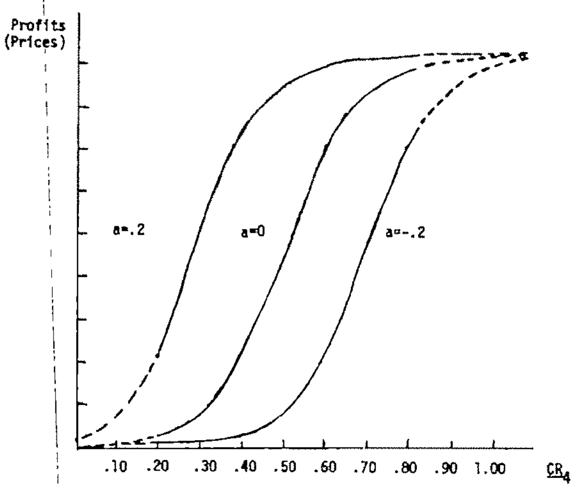


Figure 1. Examples of the S-function for different values of the shift parameter (a)

by solid lines. In this illustration, we have not allowed the curve to elongate or contract vertically; i.e., β is held constant. For different estimated values of β, the S-function can vary in slope and in its vertical expanse. The profit and price models were estimated for various preset values of (a) to determine that value of (a) in each model which minimized the standard error of the regression.

Relative firm market share (*RFMS*). A National Commission on Food Marketing study (p. 362) identifies the following practices that a firm with a strong market position may pursue to influence its profits: (a) charge higher prices; (b) offer fewer specials with sharply reduced prices, thereby selling a greater percentage of high-margin items; (c) provide fewer services to customers, thereby reducing operating costs; (d) operate stores nearer capacity, thereby capturing the lower costs of high store utilization. In addition, enterprise differentiation and advertising cost advantages are often enjoyed by a relatively dominant firm because it can engage in large-scale advertising at lower costs per unit of sales. The various real and pecuniary economies associated with a leading position in a market gives grocery retailers with large market shares an advantage over both smaller rivals and potential entrants.

The importance of a firm in a market can be measured either by firm market share (*FMS*) or by relative firm market share (*RFMS*). A firm's relative market share is the ratio of its market share to the share held by the top four firms (CR_4). Whereas *FMS* measures a firm's share of the entire market, *RFMS* measures a

firm's size relative to the leading firms in a market. We believe *RFMS* is preferable to *FMS* because a firm's discretion in pricing and its cost advantage or disadvantage depends largely on its relative position in the market. *RFMS* also has the statistical virtue that, unlike *FMS*, it is not highly correlated with CR_4; therefore, specifying it jointly with CR_4 reduces multicollinearity in the model. We hypothesize that the greater a firm's relative market share, the higher are its prices and profits, recognizing that the relationship with prices could be negative if economies of scale are substantial.

Mean store size (SS). *SS* measures the average sales per grocery store with payroll in each SMSA in 1972. This variable was included in the regression models to adjust for differences in the importance of supermarkets *vis-à-vis* small stores in various SMSAs. Because supermarkets account for about 75% of U.S. grocery store sales, set the competitive tone in most markets, and compete only indirectly with smaller grocery stores, concentration in the supermarket submarket is a better indicator of market power conditions than concentration within all grocery stores.

In markets with many small stores, the Census CR_4 (based upon all grocery stores) will be a poorer measure of supermarket concentration than in SMSAs in which small stores are a minor element. Thus, the understatement of CR_4 will be inversely related to mean store size (this results in some multicollinearity in the estimation equations). We hypothesize that *SS* will be negatively related to both profits and prices.

Market growth (MG). Market growth is defined as the percentage change from 1967 to 1972 in deflated grocery store sales in each SMSA. If capacity expansion lags behind market growth, as hypothesized, excess demand is likely to exist in the market, resulting in higher utilization of existing facilities, lower retailing costs per dollar of sales, and higher profits even if prices are not increased. Because theory does not specify the form of the relationship, *MG* is included in the profit model in nonlinear as well as linear form.

The influence of excess demand on price levels is not clear, because firm profits may be enhanced without increasing prices. Thus, while we hypothesize a positive relationship between *MG* and profits, we are unable to hypothesize the sign between *MG* and price levels.

Market size (MS). Market size is defined as the total 1972 sales for each SMSA of grocery stores with payroll. Very large SMSAs, such as New York, Los Angeles, and Chicago, actually are made up of several smaller economic markets. To the extent that retail grocery firms hold stronger market positions in certain parts of an SMSA and weaker in others, our structural variables do not accurately reflect actual market structure in the relevant submarkets. Because this problem of market fragmentation increases with the size of the SMSA, the market size variable is expected to explain some of the differences in profits which CR_4 or *RFMS* would explain if they were properly measured. From this standpoint, size is expected to be positively related to profits and price levels.

A large market also allows for larger total sales by retail firms and the potential for greater economies of scale in warehousing, physical distribution, supervision, and advertising. These factors would tend to result in somewhat lower costs and prices in large markets, all else the same. Thus, we hypothesize a positive relationship between market size and profits but are unable to predict the impact on price levels.

Impact of A&P (API). This variable measures A&P's presence as a competitor in a market or geographic area.[3] A&P was singled out as a unique competitor because of its precipitous decline in market share in many markets prior to and during the period being studied, and because of its price cutting "WEO" program launched in 1972. WEO is expected to have a negative impact on the profits of firms competing with A&P in 1972 and to a lesser extent in 1973. In the remaining years (1970, 1971, 1974), we expect A&P to be a "weak" competitor whose presence likely enhanced the profits of competing firms. *API* was not included in the price models because price data were for October 1974 when the WEO program was essentially over.

A&P Company (APC). In the division profit analysis, the *API* variable discussed above does not distinguish A&P's impact on its own profits and its impact on competitors' profits. To measure this differential impact, an A&P binary variable was specified in which A&P

[3] A&P's presence in an SMSA is measured by a binary variable. A value of one indicates that A&P operates in that SMSA and a zero indicates A&P is not present. In the divisional analysis, this variable is aggregated, as are other explanatory variables, to conform with divisional profit-sales data.

divisions were given a value of 1 and other chain divisions a value of zero. We hypothesize that *APC* will have a negative sign in both the five-year average and in the annual profit models. The absolute value of the coefficient should attain a peak in the annual regressions in 1972, the height of the WEO program.

Firm growth (*FG*). Industrial organization theory predicts the relationship between industry structure and industry performance, recognizing that individual firms may deviate from the industry average. One of the main nonstructural factors influencing individual firm profits is the caliber of management. Managerial differences are reflected in the past and current success of a chain in achieving operating efficiencies and in developing consumer preference for its services; these in turn will be reflected by the rate of firm growth. We therefore assume firm growth (*FG*) is a proxy for the relative success of a chain. *FG* is measured by the growth (excluding mergers) in each company's total grocery store sales between 1970 and 1973 (subpoenaed data were for only the first three quarters of 1974). All division and SMSA observations for a company have the same value of *FG*. We hypothesize that this variable will be positively related to a chain's profits. In addition to being specified linearly, *FG* also is specified in logarithmic form to reflect diminishing returns to managerial skills. It is not included in the price analysis because of the small number of chains involved.

Entry (*E*). Entry is included to identify and measure the impact of entry on the entering firm's profits. Because the height of entry barriers for a market are expected to affect the "cost" of entry and to be positively correlated with the level of concentration, this variable is specified accordingly. *E* has a value of zero for established firms in a market. For firms that entered a market between 1967 and 1970, *E* is measured by the 1972 four-firm concentration ratio for the SMSA, which is assumed to serve as a proxy for the height of entry barriers.

The profits of entering firms are expected to be negatively related to *E*. The extent of the profit erosion is expected to decline over the period as the entrants become established.

Market rivalry (*MR*). In many industries, including grocery retailing, firms engage in temporary competitive strategies designed to improve their position *vis-à-vis* their rivals. When such rivalry is intense, it usually is accompanied by temporarily lower prices and often leads to changes in the market shares of firms in the market. The absolute change during 1972–74 in the market shares of the four leading firms of 1974 is used as a proxy of short-run market rivalry (*MR*). We expect *MR* to be negatively associated with grocery prices; i.e., the greater the change in the leading firms' market shares (whether up or down), the lower will be grocery store prices in the SMSA affected.

Union wage rate (*WG*). Labor expense is the most important operating expense of food-retailing firms, accounting for nearly 60% of total expenses in 1974. Data on the union wage rates for meat cutters, grocery clerks, and checkers are used as a proxy variable for labor expense in our analysis.[4] We hypothesize a positive relationship between wage rates and prices. Because there is no a priori basis for expecting wage rate to be related to profits, the variable is not included in the profit models.

Dependent Variables

Profit-sales ratio (*P/S*). The profit-sales ratio for a firm in a market is defined as the net pretax profit divided by the firm's sales in that market. This ratio is an accurate measure of the price-cost margin concept introduced by Collins and Preston. Although it is necessary to control for differences in capital-sales ratios in cross-industry studies of price-cost margins, this is not necessary in an intraindustry study.

Grocery basket cost (*C*). Two price variables were constructed of the weighted cost to consumers of a "grocery basket": one variable included the national brand prices for ninety-four grocery products plus private label prices for about one-half of these products (for products with both national brand and private label prices, a weighted product price was calculated using national brand and private label market shares); the second variable included only national brand prices. The price data were for October 1974.

---

[4] The variable was calculated using data for 1974 from BLS, Retail Clerks International, and Amalgamated Meat Cutters and Butcher Workmen of North America. Meat cutter, grocery clerk, and checker wage rates were weighted by the percentage that each category of labor represented of retail labor expense.

Profit Models

Division and SMSA profit-sales ratios were examined using the following basic models:

$$(1)\ SMSA\ P/S = \beta_0 + \beta_1 RFMS + \beta_2 CR_4 + \beta_3 SS + \beta_4 E + \beta_5 FG + \beta_6 MG + \beta_7 MS + \beta_8 API + \epsilon,$$

HYPOTHESIS: $\beta_1 > 0 \quad \beta_2 > 0 \quad \beta_3 < 0 \quad \beta_4 < 0 \quad \beta_5 > 0 \quad \beta_6 > 0 \quad \beta_7 > 0 \quad \beta_8 > 0$;

$$(2)\ \text{Division } P/S = \alpha_0 + \alpha_1 RFMS + \alpha_2 CR_4 + \alpha_3 FG + \alpha_4 MG + \alpha_5 MS + \alpha_6 APC + \alpha_7 API + \epsilon,$$

HYPOTHESIS: $\alpha_1 > 0 \quad \alpha_2 > 0 \quad \alpha_3 > 0 \quad \alpha_4 > 0 \quad \alpha_5 > 0 \quad \alpha_6 < 0 \quad \alpha_7 > 0$,

where P/S is divisional or SMSA profit-sales ratio; *RFMS* is 1972 relative firm market share; CR_4 is 1972 four-firm concentration ratio (curvilinear form of this variable (CCR_4) was used in several models); *SS* is 1972 mean sales per grocery store within an SMSA; *E* identifies the SMSAs which sample firms entered between 1967 and 1970 (the 1972 CR_4 in these markets is used as an estimate of entry barriers); *FG* is firm growth as measured by the percentage increase in grocery store sales between 1970 and 1973; *MG* is market growth, measured by the 1967 to 1972 percentage increase in deflated grocery store sales in a SMSA or division; *MS* is 1972 market size (dollar grocery store sales); *APC* is a binary identifying A&P division; *API* is variable used to indicate the presence or absence of A&P in a market or division; and ϵ is the error term.

Results of Profit Analysis

Two data sets were used to explore structure-profit relationships. The first set was for six chains in fifty Standard Metropolitan Statistical Areas (SMSAs). There were seventy-two observations, because in some instances more than one of the firms operated in an SMSA. The second data set included ninety-six divisions of twelve food chains. Because the SMSA data do not involve aggregating the market structure and control variables to a divisional basis, the regression analysis of SMSA profits is more discriminating than the divisional analysis.

SMSA Profit Analysis

The hypothesized relationship between market structure and profit rates, P/S, is assumed to be long-run in nature. Temporary price wars or labor strikes may distort this relationship in some areas in a particular year. The most common method of controlling for such short-term disturbances in market structure-profit models is to average the data for several years on the assumption that short-run aberrations will be offsetting overtime (Weiss). Five-year average profit rates for 1970–74 are used in the first three regression models shown in table 1.

Equation (1a) is a linear model including six independent variables.[5] All of the variables have the hypothesized sign and are statistically significant at the 5% level except *MS*. Equation (1b) introduces mean store size (*SS*), which has the expected negative sign and predictably strengthens the t value for CR_4. Equation (1c) adds the A&P impact variable (*API*) to the model and includes nonlinear functional forms for CR_4, firm growth, market growth, and market size. It is our preferred model. *RFMS* and the curvilinear forms of firm growth, market growth, and market size have a stronger relationship to profits in this model than in the first two equations. The nonlinear form of CR_4 becomes significant at the 1% level. Setting the shift parameter (α) at .2 minimized the standard error of the regression. Within the sample range the concentration-profits curve rises rapidly until $CR_4 = 60$, whereafter it continues to rise at a modest rate. No threshold level was detected at low levels of concentration.

Mean store size (*SS*) has the expected negative sign, but it is not significant in this equation. Firm growth, which is introduced in logarithmic form (*LNFG*) in this equation, has the expected negative sign and is highly significant. This finding substantiates the hypothesis that the profit rates of an individual chain are determined by factors unique to it as well

[5] As in previous structure-profit studies that used firm data as the unit of observation, both samples are heteroscedastic. When ordered by firm growth, the variance of the regression residuals became progressively larger as firm growth decreased. This suggests that poorly managed firms have both lower and more variable rates of profit, *ceteris paribus*. To construct the generalized weighting matrix, it was assumed that the residual variance was proportional to the natural logarithm of firm growth. The unweighted test results are not appreciably different from the reported results.

Table 1. Multiple Regression Equations Explaining SMSA Profit-Sales Ratios for Six Companies in 50 SMSAs, 1970–74

Dependent Variable: Profit-Sales Ratio (P/S)	Intercept	Independent Variables[b]: Relative Firm Market Share (*RFMS*)	4-Firm Concen-tration Ratio (CR_4)	Curvi-linear 4-Firm Concen-tration (CCR_4)[a]	Mean Store Size (*SS*)	Entry (*E*)	Firm Growth (*FG*)	Log Firm Growth (*LNFG*)	Market Growth (*MG*)	Market Growth Squared (MG^2)	Market Size (*MS*)	Market Size Squared (MS^2)	A&P Impact (*API*)	R^2	*F* Value
1a 1970–74 average	−3.579	.062	.023			−.046	.044		.030		.122			.817	41.33**
		(5.677)**	(1.786)*			(6.104)**	(6.694)**		(2.904)**		(.706)				
1b 1970–74 average	−3.137	.062	.030		−1.000	−.044	.045		.029		.254			.825	37.75**
		(5.697)**	(2.273)*		(1.715)*	(5.846)**	(6.892)**		(2.884)**		(1.356)†				
1c 1970–74 average	−8.098	.065		3.020	−.524	−.032		1.719		.049	−1.805	.577	.380	.856	36.69**
		(6.691)**		(2.117)**	(.830)	(4.461)**		(7.796)**		(3.431)**	(3.057)**	(3.440)**	(1.261)†		
2 1970	−8.351	.083		8.228	−.767	−.062		.959		.046	−3.260	.985	−1.089	.699	24.19**
		(4.106)**		(2.757)**	(.585)	(4.198)**		(2.081)*		(1.527)†	(2.630)**	(2.799)**	(1.742)*		
3 1971	−8.061	.085		5.178	−.115	−.036		1.266		.057	−2.232	.656	.630	.788	23.08**
		(5.381)**		(2.308)**	(1.245)	(4.038)**		(3.453)**		(2.793)**	(2.417)**	(2.514)**	(1.427)†		
4 1972	−9.341	.069		1.649	−.257	−.032		2.155		.062	−1.595	.537	.675	.814	27.26**
		(5.448)**		(.913)	(.338)	(4.182)**		(7.362)**		(3.729)**	(2.132)*	(2.539)**	(1.873)*		
5 1973	−8.402	.057		.640	−.271	−.015		2.215		.044	−1.800	.585	.964	.773	21.16**
		(4.978)**		(.380)	(.363)	(1.717)*		(8.633)**		(2.524)**	(2.603)**	(2.970)**	(2.670)**		
6 1974	−9.223	.042		.444	−.644	−.021		2.334		.016	.781	.248	1.411	.852	35.66**
		(3.887)**		(.285)	(.965)	(3.094)**		(9.307)**		(1.071)	(1.202)	(1.349)†	(4.472)**		

Note: There are 72 observations from these 50 SMSAs, because in several instances more than one of the firms operated in an SMSA. One observation was deleted from the 1970 sample because of a prolonged labor dispute. One-tailed tests were used in all cases. Significance levels: ** = 1%; * = 5%; † = 10%.

[a] $CCR_4 = (CR_4 + \alpha)^3/1 - 3(CR_4 + \alpha) + 3(CR_4 + \alpha)^2$. This function of CR_4 has positive slope and is symmetric about an inflection point. The inflection point of the curve occurs at the concentration ratio which satisfies the following equation: $CR_4 = 0.5 - \alpha$. For all equations in this table $\alpha = 0.20$, so the inflection point of the curve is $CR_4 = 0.30$.

[b] *P/S*, *RFMS*, CR_4, and *FG* are expressed as percentages. *LNFG* is the natural logarithm of *FG*; *MG* is expressed in percentages; MG^2 is the percentage of market growth squared and divided by 100; *MG* is expressed in billions of dollars; *SS* is expressed in million dollar sales per store; *E* is expressed in percentage.

as by the structure of the markets in which it operates.

Market growth is introduced quadratically (MG^2), is significant at the 1% level, and has the hypothesized positive sign. Profits tend to increase at an increasing rate as the rate of market growth increases.

Market size is introduced as a complete quadratic (MS, MS^2) and is significant at the 1% level. For SMSAs in which grocery store sales exceeded $1.6 billion, there is a positive relationship between profits and market size. This is consistent with the original hypothesis on scale economies and market misdefinition. Most market sales, however, are less than $1.6 billion (approximate size of San Francisco-Oakland SMSA). For SMSAs smaller than $1.6 billion, market size is negatively related to profits, which is contrary to the hypothesized relationship. One possible explanation is that many of the chains in the sample operate a substantial number of stores in low income areas of large cities, where profits tend to be low (D. R. Marion). Chains may have relatively higher profits in small- and medium-sized cities than in large cities, where the cost-increasing factors associated with central city operations are most common. This would account for a negative relationship between profits and market size over a wide range of market sizes; the relationship becomes positive for very large cities, where the effect of market misdefinition is sufficiently great to offset the influence of low profits in central cities.

The A&P impact (*API*) variable has the expected positive relationship to the profits of competing chains and is significant at the 10% level. (A&P was not one of the six chains in this sample.)

The model shown in equation (1c) is tested for individual years in equations (2) through (6). The results are generally consistent with those discussed above; however, several of the variables behave in a markedly different manner in particular years. The market structure, entry, and firm growth variables always have the expected sign and, except for CR_4, are always significant at the 5% level. This is a remarkably strong showing for analyses based on data for individual years. The entry variable (E) is negative and statistically significant in all years. As expected, the value of the regression coefficient is greatest in 1970 and declines thereafter.

The *API* variable behaves rather erratically in the SMSA models for individual years. This is partly attributable to collinearity with mean store size and CCR_4.

The most significant finding of the multiple regression analysis of SMSA profits is that in equations (1a), (1b), and (1c), the two structural variables, *RFMS* and CR_4, have the expected positive signs and are statistically significant in all cases. The results indicate that the higher a firm's *RFMS* and the higher the level of four-firm concentration in an SMSA, the greater are the firm's profits.

Division Profit Analysis

Divisional profit and sales data were provided by twelve chains for ninety-six divisions. The same basic variables and functional forms were used in the divisional analysis as the SMSA analysis. Two variables included in the SMSA analysis, mean store size (*SS*) and entry (E), were not included in the divisional models.[6] One additional variable, A&P company (*APC*), was included since A&P was one of the twelve chains in this sample.

Both equations using average P/S data from 1970–74 are statistically significant at the 1% level (table 2). The two structural variables, *RFMS* and CR_4, have the hypothesized positive sign and are statistically significant at the 1% level except when CR_4 is in linear form, equation (1a). In equation (1b), which is the most complete model, *RFMS* and CR_4 are significant at the 1% level.

Equations (1a) and (1b) are similar except that the A&P impact variable is included in (1b) and nonlinear functional forms are specified for CR_4, firm growth, market growth, and market size. All variables in equation (1b) are statistically significant at the 1% level except *API*, which is significant at the 10% level. In the statistical significance and signs of the independent variables, the divisional regression results are very similar to the SMSA regression results already discussed.

The A&P company (*APC*) variable, which was included only in the division models, has the hypothesized negative sign and is statistically significant in both equations (1a) and (1b). This result supports the hypothesis that during the 1970–74 period, the WEO

[6] This was done to simplify the model. Divisional variables were developed by aggregating data from different SMSAs within a division. E is particularly difficult to measure in this case because a chain may be operating in some SMSAs in a division at the same time it is entering another.

Table 2. Multiple Regression Equations Explaining Division Profit-Sales Ratios for 12 Companies, 96 Divisions, 1970–74

Dependent Variable	Independent Variables[b]													
Profit-Sales Ratio (*P/S*)	Intercept	Relative Firm Market Share (*RFMS*)	4-Firm Concentration Ratio (CR_4)	Curvilinear 4-Firm Concentration Ratio (CCR_4)[a]	Firm Growth (*FG*)	Log Firm Growth (*LNFG*)	Market Growth (*MG*)	Market Growth Squared (MG^2)	Market Size (*MS*)	Market Size Squared (MS^2)	A&P Company (*APC*)	A&P Impact (*API*)	R^{2c}	*F* Value
1a 1970–74 average	−3.103	0.074	0.011		0.045		0.040		−0.136		−0.792		.849	71.61**
		(8.012)**	(0.829)		(7.948)**		(4.283)**		(0.874)		(2.734)**			
1b 1970–74 average	−8.232	0.063		3.473		1.543		0.065	−1.770	0.501	−1.115	0.348	.894	81.19**
		(7.540)**		(2.600)**		(8.524)**		(4.708)**	(3.238)**	(3.085)**	(3.852)**	(1.494)†		
2 1970	−6.439	0.069		3.246		1.118		0.080	−2.367	0.731	−0.867	0.593	.805	39.86**
		(5.776)**		(1.693)*		(4.227)**		(3.733)**	(3.114)**	(3.217)**	(2.338)*	(1.663)*		
3 1971	−8.108	0.063		5.374		1.139		0.068	−2.449	0.674	−1.191	0.470	.810	41.33**
		(5.430)**		(2.879)**		(4.463)**		(3.357)**	(3.286)**	(3.026)**	(3.184)**	(1.387)†		
4 1972	−10.834	0.072		5.369		1.665		0.083	−1.895	0.542	−2.433	0.080	.808	40.70**
		(5.938)**		(2.750)**		(6.287)**		(4.056)**	(2.397)**	(2.304)*	(5.923)**	(0.231)		
5 1973	−7.371	0.054		0.315		1.886		0.078	−1.001	0.317	−0.678	0.467	.859	58.69**
		(5.474)**		(0.206)		(8.610)**		(5.213)**	(1.462)†	(1.587)†	(1.708)*	(1.827)*		
6 1974	−6.221	0.057		1.173		1.682		0.037	−1.021	0.224	−0.407	0.257	.813	42.02**
		(5.204)**		(0.666)		(6.942)**		(1.875)*	(1.460)†	(1.072)	(1.182)	(0.792)		

Note: 1-tail tests were used in all cases; significance levels: ** = 1%; * = 5%; † = 10%.
[a]Same as [a] in table 1.
[b]Same as [b] in table 1.
[c]Because of computation procedures, R^2 values in tables 1 and 2 are not comparable to those in table 3.

discount-pricing program (as well as other factors) had a negative impact on A&P profits. Insofar as WEO resulted in a uniformly lower rate of profit for each A&P division, independent of market structure, the *APC* variable is an effective means of control. However, if A&P's offensive tactics were not independent of market structure, then the coefficients in table 2 are biased. To test this, the model was rerun excluding the A&P observations from the sample (JEC Rep., p. 52). The five-year average model had similar results to its counterpart, equation (1b) in table 2. These results indicate that *APC* is an effective control for A&P's unique strategies and does not bias the coefficients in table 2.

Model (1b) is tested for individual years in equations (2) through (6). The results are similar to those in equation (1b) and are surprisingly strong for individual year data. *RFMS* and *FG* are statistically robust in all five of the individual year equations. CR_4 is statistically significant for the 1970, 1971, and 1972 equations, but as in the SMSA analysis, becomes insignificant in the 1973 and 1974 equations. The A&P impact variable (*API*) generally performs as hypothesized.

Price Analysis

The preceding analysis indicates that high profit levels were associated with high relative firm-market shares and concentrated markets. These results suggest that high profits are due, in part at least, to higher prices. In this section, the relationship between prices and market structure is examined directly.

The cost to consumers of a grocery basket of ninety-four products varied considerably across markets—12% or more for each chain. Multiple regression was used to test the hypothesized relationships between "grocery basket" costs and market structure variables, plus several control variables. The basic model employed was[7]

$$C = \beta_0 + \beta_1 RFMS + \beta_2 CR_4 + \beta_3 SS + \beta_4 MG + \beta_5 MS + \beta_6 MR + \beta_7 WG + \epsilon,$$

HYPOTHESES:

$$\beta_1 > 0 \quad \beta_2 > 0 \quad \beta_3 < 0 \quad \beta_4 \neq 0 \quad \beta_5 \neq 0 \quad \beta_6 < 0 \quad \beta_7 > 0,$$

where *C* is the weighted cost of a grocery basket consisting of either national brand and private label items (*NPC*), or national brand items only (*NC*); *RFMS* is relative firm market share in 1974 (a curvilinear form of this variable (*CRFMS*) was also employed in some models); CR_4 is four-firm concentration ratio in 1974 (a curvilinear form of this variable, CCR_4, was used in several models); *SS* is 1972 mean store size in each SMSA measured in dollars of sales per grocery store; *MG* is 1967–74 percentage growth in SMSA grocery store sales; *MS* is 1974 SMSA size (dollar grocery store sales); *MR* is market rivalry, measured as the absolute change between 1972 and 1974 of the combined market share of the four leading firms of 1974; *WG* is the weighted average of 1974 union wage rates for meat cutters, grocery clerks, and checkers in each SMSA, and ϵ is the error term.

In the results presented in table 3, additional independent variables are progressively included as one moves from equation (1a) to (1c). Adding the market rivalry variable, equation (1b), nearly doubles the explanatory power of the model and substantially increases the significance of CR_4 and market growth.

Equations (1e) and (1f) include the union wage rate variable (*WG*), which has the predicted sign but is not statistically significant in either equation. Union wage rate was collinear with store size. However, *WG* is not significant in equation (1e), which does not include store size. Thus, collinearity between *WG* and *SS* does not appear to account for the former's lack of significance. While this finding indicates that wage rate, the nondiscretionary element of labor expense, does not explain a significant amount of the variation in prices, it provides no indication of whether the competitive emphasis or the productivity of labor results in higher labor expense in higher-priced markets. The latter factors are subject to the discretion of management and may be influenced by the competitive environment.

Equations (1g), (1h), and (2h) include curvilinear forms of CR_4 and/or *RFMS*. Comparing models (1g) and (1b), the curvilinear form of four-firm concentration (CCR_4) strengthens the significance of *RFMS* but slightly reduces the significance of four-firm concentration and market rivalry.

[7] While firm growth (*FG*) was found highly significant in the profit models, it was not significant when included in the price models. The variable, entry (*E*), was not specified in a price model due to inapplicability. Market rivalry (*MR*), which was highly significant in the price models, was not significant when incorporated in a profit model.

Table 3. Multiple Regression Equations Explaining Cost of a Grocery Basket of Three Chains in 36 SMSAs, 1974

Equation Number[a]	Intercept	Relative Firm Market Share (*RFMS*)	Curvilinear Relative Firm Market Share (*CRFMS*)[b]	Four-Firm Concentration (CR_4)	Curvilinear Four-Firm Concentration (CCR_4)[b]	Mean Store Size (*SS*)	Market Growth (*MG*)	Market Size (*MS*)	Market Rivalry (*MR*)	Union Wage Rate (*WG*)	$\bar{R}^2$	*F*-Value
1a NPC	91.05	10.284 (3.475)**		11.957 (2.796)**		−.007 (−3.141)**	−.062 (−2.405)*				.38	6.30**
1b NPC	90.67	6.582 (2.882)**		15.645 (4.864)**		−.006 (−3.148)**	−.078 (−4.067)**		−.475 (−5.247)**		.66	14.87**
1c NPC	90.67	6.449 (2.714)**		15.259 (4.249)**		−.005 (−1.931)*	−.078 (−3.975)**	−.158 (−.259)	−.485 (−4.875)**		.65	12.02**
1d NPC	89.93	5.025 (2.130)*		11.121 (3.694)**			−.066 (−3.400)**	−1.019 (−2.333)*	−.562 (−5.917)**		.62	12.53**
1e NPC	84.09	6.464 (2.326)*		8.707 (2.483)**					−0.471 (−4.287)**	0.852 (0.792)	.49	9.22**
1f NPC	86.66	6.426 (2.932)**		16.545 (5.256)**		−.006 (−3.070)**		−.082 (−4.169)**	−.501 (−5.154)**	.666 (0.662)	.70	14.29**
1g NPC	96.73	7.112 (3.048)**			7.781 (4.565)**	−.006 (−3.069)**	−.075 (−3.837)**		−.461 (−4.981)**		.65	13.77**
1h NPC	97.51		3.624 (3.364)**		7.416 (4.425)**	−.006 (−3.169)**	−.074 (−3.890)**		−.458 (−5.089)**		.66	14.79**
2b NC	90.74	6.604 (2.929)**		14.624 (4.607)**		−.004 (−2.048)*	−.069 (−3.655)**		−.527 (−5.898)**		.68	15.83**
2h NC	97.20		3.638 (3.470)**		6.988 (4.285)**	−.004 (−2.141)*	−.066 (−3.522)**		−.511 (−5.837)**		.69	16.38**

Note: Figures in parenthesis are *t*-values. The statistical significance of the regression coefficients for *RFMS*, *CRFMS*, CR_4, CCR_4, *SS*, and *MR* were tested by means of a one-tail *t*-test; *MG* and *MS* were tested by means of a two-tailed *t*-test. The adjusted coefficients of multiple determination were tested by means of *F*-ratio. * and ** indicate the regression coefficients are statistically significant at the 5% and 1% levels, respectively.

[a] The independent variable (*NPC*) in equations (1a)–(1h) is the cost of a grocery basket of national brand and private label products. The dependent variable (*NC*) in equations (2b) and (2h) is the cost of a grocery basket of only national brand products. All equations have 36 observations except (1e) and (1f), where one SMSA was omitted due to lack of union wage data.

[b] *CRFMS* and $CCR_4 = (x + \alpha)^3/[1 - 3(x + \alpha) + 3(x + \alpha)^2]$, where x equals *RFMS* or CR_4. Values for each variable were expressed in decimals between zero and one. The function of *CRFMS* and CCR_4 has a positive slope and is symmetric about an inflection point. The inflection point occurs at the point which satisfies the following equation: $I = .5 - \alpha$, where I equals the inflection point. For *CRFMS*, the inflection point for each of the above equations was .35 (i.e, $\alpha = .15$). For CCR_4, the inflection point for each of the above equations was .63 (i.e., $\alpha = -.13-$).

Equations (1h) and (2h) include the curvilinear forms of both four-firm concentration (CCR_4) and relative firm market share (*CRFMS*). Overall, these are similar to the best linear models (1b and 2b). In comparing the b and h models, the main difference is the trade-off in significance of *RFMS* and CR_4. Neither model is superior on statistical grounds.

In all but three instances, the independent variables shown in table 3 are statistically significant and have the hypothesized signs. Of particular importance is the consistent positive and significant relationship of the market structural variables (*RFMS* and CR_4) to grocery prices. These results indicate that *RFMS* and CR_4 exercise an independent positive influence on grocery prices.

Average store size (*SS*) has the expected negative relationship to prices. Because *SS* provides a partial correction for the understatement of CR_4 in some markets, the negative relationship between *SS* and prices reinforces the positive relationship between CR_4 and prices.[8]

Market growth (*MG*) is negatively related to prices in all equations, indicating that chains had lower prices in rapidly growing markets. Not unexpectedly, this is contrary to the findings of the profit equations which found a statistically significant positive relationship between market growth and firm profits.

Because of the collinearity between average store size and market size ($r = .60$), the relationship of these variables to grocery prices is muted when both variables are included in the model, e.g., equation (1c). When mean store size is excluded in equation (1d) market size has the predicted negative relationship to grocery prices and is statistically significant.

Market rivalry (*MR*) has the predicted negative sign and is highly significant in all equations in which it was included. *Ceteris paribus,* prices are lowest in markets where firm rivalry is most intense. The variable increases the statistical significance of CR_4 and *MG*. The significance of *RFMS* declines but remains highly significant.

Equations (2b) and (2h) include the same independent variables as equations (1b) and (1h) but use as the dependent variable a grocery basket consisting solely of national brand products (*NC*). The *NPC* and *NC* results are similar, indicating that the inclusion of private label products in the grocery basket had little effect on the statistical findings.

Limitations on Regression Results

The estimates and interpretations of the preceding regression analyses are necessarily influenced by the nature and quality of the data used in making them. One possible source of error is that the price comparison data were available for only one month. We have no reason to believe this biases the results upward or downward. This short period could lower the level of statistical significance of the analysis because short-term random factors cannot be reduced by averaging data over longer periods. Indeed, there is evidence that temporary price distortions reduced the level of significance of our findings.[9]

Another possible source of error is that the regression analysis was based solely on a basket of grocery products. However, for a more limited number of SMSAs, the cost of the grocery basket was closely correlated with the cost of a market basket including additional product groupings.

A third possible source of error is that the items price-checked by the sample chains were likely considered the most price sensitive or "competitive" and therefore were not representative of nonchecked items. However, there is no a priori reason for believing that if a firm could elevate prices for the checked items in noncompetitive markets, it could not likewise raise prices on less sensitive items.

Fourth, the results are based upon the pricing behavior of only three large chains in thirty-two different SMSAs. The firms and metropolitan areas included in the analysis were selected because of data availability, not because of their representativeness. However, the three firms included in our analysis repre-

[8] Supermarket concentration ratios were obtained from the Bureau of Census after the JEC Report was completed. Replacing the grocery store *RFMS* and CR_4 with supermarket *RFMS* and CR_4 had little effect on the regression results. However, average store size (*SS*) became insignificant in the supermarket models, as expected.

[9] In June 1977, newspaper food editors surveyed the cost of a 35 item market basket in 19 cities. Five of the cities were in our sample. Despite differences in sample design and the lapse of nearly three years, the relative prices in the 5 cities were nearly identical in the two samples except for Denver, which was substantially higher in 1977 than in 1974. Denver was a large outlier in our analysis with actual prices below those expected, given its high CR_4 and *RFMS*. However, its prices were temporarily depressed in 1974 due to intense, short-term price rivalry (JEC, pp. 32–39).

sent a reasonable cross section of the twenty largest chains in terms of profitability, growth, and average firm market share. The thirty-two SMSAs in the price analysis had a weighted mean CR_4 of 48.8 for 1972; this compares to 49.6 for the 263 SMSAs included in the 1972 Census. Thus, while caution is warranted in interpreting the results, we have no grounds for believing that our results are atypical for food retailing.

Implications

The structure-price findings lend considerable support to the structure-profit relationships discussed earlier. They also suggest that higher observed profits are due largely to the higher prices chains are able to charge in less competitively structured markets. This conclusion holds irrespective of the functional form used for CR_4.

The equations can be used to estimate the magnitude of the influence of *RFMS* and CR_4 on prices and profits of individual chains (JEC Report, p. 77). Holding other variables at their means, the predicted prices and profits with four structural combinations are as follows:

		Predicted	
RFMS	CR_4	Index of Prices	Profit-Sales Ratio
10	40	100.0	0.37
25	50	101.7	1.77
40	60	105.4	2.78
55	70	108.9	3.62

Comparing the extreme structural combinations indicates a price difference of 8.9% and a profit difference of 3.25 percentage points. The increase in profits accounts for only 36% of the predicted increase in prices.

Caution must be exercised in making direct comparisons between the price and profit analysis because they are based on somewhat different samples. Nonetheless, they provide no support for the notion that high market concentration and/or high individual chain market shares result in higher profits because of economies of scale and lower costs. Rather, the analysis suggests the opposite. As *RFMS* and/or CR_4 increase, a chain's prices increase more rapidly than its profits—suggesting that costs also increase.

Our results also indicate that the greater costs in noncompetitive markets are not attributable to higher wage rates or transportation costs (JEC, p. 88–89), factors that are largely outside of managerial control. Rather, the higher costs appear to be due to inefficiencies and cost-increasing forms of competition. Other studies have found that market power stimulates inflated costs and inefficiencies as well as higher prices. Our results suggest that this is also true in food retailing.

Our analysis provides strong evidence that consumers pay substantially more in highly concentrated markets dominated by one or two firms than in less concentrated markets without a dominant firm.[10] However, many retail markets are still quite competitively structured. Moreover, many independents and small chains, as well as large chains in many of their markets, do not have significant market power. We emphasize this point lest our findings are misinterpreted as implying that all retailers have market power. However, the number of highly concentrated markets (CR_4 over 60) has increased substantially—from 5% of SMSAs in 1954 to 25% in 1972—and is likely to increase further unless public policy intervenes. Obviously, high priority should be given to policies that will stop this trend or otherwise improve the competitive performance of this important industry (JEC, p. 19–28).

[*Received July 1978; revision accepted March 1979.*]

References

Dalton, James, and David Penn. "The Concentration Profitability Relationship: Is There a Critical Concentration Ratio?" *J. Indust. Econ.* 25(1976):133–43.

Marion, Bruce W., Willard F. Mueller, Ronald W. Cotterill, Frederick E. Geithman, and John R. Schmelzer (JEC Report). *The Profit and Price Performance of*

[10] We estimate the overcharge to consumers due to noncompetitive retail markets was $662 million in 1974 (JEC Report, p. 80–82). While we are confident that this is a conservative estimate, it has been the major point of controversy about the study. We omitted the discussion from this paper in order to emphasize the most important findings of our study, namely, the strong positive relationship between market structure and firm prices and profits.

Leading Food Chains, 1970–1974. Joint Economic Committee, Congress of the United States, 12 April 1977.

Marion, Donald R. "Food Retailing in Low Income Areas—An Economic Analysis." Amherst: University of Massachusetts, June 1974.

National Commission on Food Marketing. *Organization and Competition in Food Retailing*. Tech. Stud. No. 7. June 1966.

Rhoades, Stephen. "The Concentration-Profitability Relationship: Policy Implications and Some Empirical Evidence." *The Antitrust Bull.* Fall (1973):353–54.

U.S. Congress, Joint Economic Committee (JEC). *Prices and Profits of Leading Retail Food Chains, 1970–1974*. Washington, D.C., U.S. Government Printing Office, 1977.

Weiss, Leonard W. "The Concentration Profit Relationship and Antitrust." *Industrial Concentration: The New Learning*, ed. H. J. Goldschmid, H.M. Mann, J. F. Weston. Boston: Little, Brown & Co., p. 131, 1974.

White, Lawrence. "Searching for the Critical Concentration Ratio: An Application of the 'Switching of Regimes' Technique." *Studies in Nonlinear Estimation*, ed. S. M. Goldfeld and R. E. Quandt. Cambridge, Mass.: Ballinger Publishing Co., 1976.

The Influence of Domestic Pricing Policies and Buffer Stocks on Price Stability in the World Wheat Industry

A. C. Zwart and K. D. Meilke

Domestic pricing policies are a major cause of instability in international commodity markets. The modification of such policies could be a viable alternative to buffer stocks in providing stability. A theoretical model of price intervention is developed to show how common forms of intervention destabilize the world market price. A stochastic econometric model is used to show, first, that most countries in the world wheat market have policies which destabilize the wheat market, and, second, that the modification of such policies would prove as effective as a buffer stock policy in stabilizing the wheat market.

Key words: buffer stock, domestic policies, price stability, stochastic simulation, world wheat industry.

The instability of world grain markets in the past few years has focused attention on the need for stabilization policies. There has been considerable discussion in the literature of the desirability and likely impacts of alternative stabilization policies, but the major emphasis has been on physical reserves or buffer stock policies as the appropriate mechanism for attaining stability.

While there was a realization that domestic trade policies could influence the stability of world prices (Johnson, Josling, Konandreas and Schmitz), there have been few attempts to quantify this influence. Theoretical studies by Just, Lutz, Schmitz, and Turnovsky; and Bieri and Schmitz have shown that domestic pricing or stabilization policies can have an influence on the distribution of welfare gains from buffer stock policies, but they treat the presence of such policies as the special case rather than the norm. Thus, the modification of such policies is not considered as a viable alternative to a stock policy.

Studies by Shei and Thompson, and Grennes, Johnson, and Thursby have measured the stabilizing influences of changing specific domestic policies in the 1972/73 and 1973/74 crop years. These static analyses have shown that domestic agricultural policies which do not allow international price changes to be reflected in domestic price changes increase the instability of world prices, and it is suggested that more flexible domestic policies are an alternative to buffer stock policies.

The aim of this article is to develop a more general model of domestic policy intervention. This general model, which need not be related to any specific policy instrument, can be used to show conditions under which domestic policies will influence world price stability. A stochastic simulation model of the world wheat industry is used to compare the impacts of a buffer stock policy with that of changing pricing policies in individual countries. These simulation experiments provide a measure of the price instability caused by domestic pricing policies and indicate the size of an international buffer stock that would be necessary to overcome this instability.

A Theoretical Model

A simple two-region supply and demand model is utilized to show the effects of domestic price intervention on world price stability.

A. C. Zwart is lecturer in agricultural economics, Lincoln College, New Zealand, and K. D. Meilke is associate professor of agricultural economics, University of Guelph.

This project was supported by Agriculture Canada and the Ontario Ministry of Agriculture and Food.

The authors would like to thank the reviewers for helpful comments.

It is assumed, only for simplicity, that the importing region has a domestic pricing policy and that it applies to both consumers and producers within the region. For ease of exposition, the only source of instability is assumed to be random supply shifts in both regions. With these assumptions, the model can be represented by equations (1) through (5):

$$(1) \qquad DE = a - bPW,$$

$$(2) \qquad SE = c + dPW + U_1,$$

$$(3) \qquad DI = e - fPD,$$

$$(4) \qquad SI = g + hPD + U_2, \text{ and}$$

$$(5) \qquad SE - DE = DI - SI,$$

where, DE is demand in the exporting region, SE is supply in the exporting region, DI and SI are, respectively, demand and supply in the importing region, PW is the world price and PD the domestic price of the commodity, U_1 and U_2 are random error terms independently distributed as $N(0, \sigma_1^2)$ and $N(0, \sigma_2^2)$, respectively, and a through h are supply and demand parameters.

Consider first the case of no intervention. In this situation the domestic price equals the world price, i.e., $PD = PW$ and the equilibrium can be determined from (5), i.e.,

$$(6) \qquad PW = \frac{e - g - U_2 + a - c - U_1}{d + b + f + h}.$$

The expected value of PW is

$$(7) \qquad E(PW) = \frac{e - g + a - c}{d + b + f + h},$$

and the variance of world price, because U_1 and U_2 are independent, is

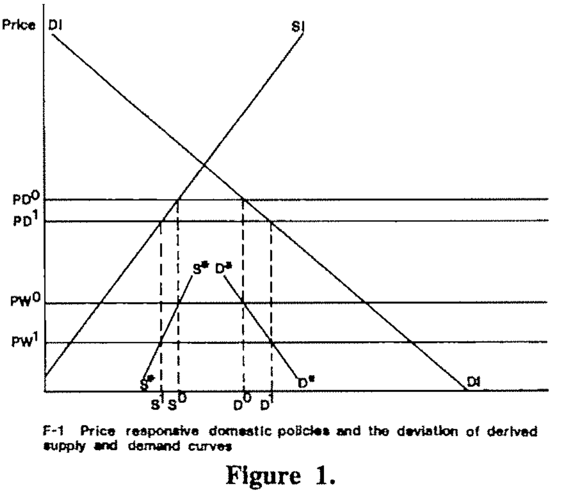
$$(8) \qquad \text{Var}(PW) = \frac{\sigma_1^2 + \sigma_2^2}{(d + b + f + h)^2}.$$

Excess supply equals excess demand at the world price. The variance of price depends on the supply variances and the price response coefficients in both regions.

Now consider a simple form of price intervention,

$$(9) \qquad PD = \alpha + \gamma PW.$$

This intervention rule states that the domestic price is a function of the world price and α and γ represent policy parameters. Lattimore has estimated these types of relationships in more detail for the Brazilian beef sector and has shown that they are complex and possibly nonlinear. However, the general form of the intervention relationship is retained as it represents many alternative types of policies. In the free market situation, the relevant policy parameters are $\alpha = 0$ and $\gamma = 1$. An absolute and invariant tariff implies $\alpha > 0$ and $\gamma = 1$, i.e., the domestic price equals the world price plus α. An ad valorem tariff can be represented by $\alpha = 0$, and $\gamma > 1$. These simple types of policy are obvious, but a more interesting interpretation of the intervention rule is that it explains the manner in which the domestic price (PD) changes as the world price of the commodity changes. For example, even though a tariff or quota may be the instrument used, the levels of these variables change over time as world price levels and domestic economic conditions vary. Because the changes in these variables are the major consideration of this analysis, the specific type of policy instrument used is relatively unimportant. Instead, the policy parameters α and γ should be viewed as the net impact of a combination of instruments which are used to establish a domestic price that reflects the pricing objectives of the government. In figure 1, with a world price of PW^0 and a corresponding support level of PD^0, the importing country produces S^0 and demands D^0. Now if the world price drops to PW^1, the domestic price may drop to PD^1, with domestic supply falling to S^1 and demand increasing to D^1. This action reduces the level of transfer payments within the economy that would have been necessary had the domestic support price been maintained at PD^0. If the response of the importing



F-1 Price responsive domestic policies and the deviation of derived supply and demand curves

Figure 1.

country to changes in world price is consistent over time, then it is possible to derive the response curves S^*S^* and D^*D^* (fig. 1). The demand and supply relationships D^*D^* and S^*S^* can be considered policy-inclusive derived demand and supply curves, showing the change in domestic demand and supply resulting from a world price change. These relationships represent the relevant supply and demand curves which respond to and affect the world price. They can be derived mathematically by substituting the price intervention relationship (9) into the domestic supply and demand curves, giving

$$DI = e - f\alpha - f\gamma PW, \text{ and} \tag{10}$$

$$SI = g + h\alpha + h\gamma PW. \tag{11}$$

Using this general type of domestic price intervention, it is possible to solve for the expected value and variance of world price,

$$E(PW) = \frac{e - g + a - c - \alpha(f + h)}{d + b + \gamma(f + h)}, \tag{12}$$

and

$$\mathrm{Var}(PW) = \frac{\sigma_1^2 + \sigma_2^2}{[d + b + \gamma(f + h)]^2}. \tag{13}$$

It also can be shown that the variance of the domestic price is

$$\mathrm{Var}(PD) = \frac{\gamma^2(\sigma_1^2 + \sigma_2^2)}{[d + b + \gamma(f + h)]^2} = \gamma^2\mathrm{Var}(PW). \tag{14}$$

The above results reveal the effect of the general type of policy intervention on the level and stability of world price. It can be seen that alternative levels of the policy parameters α and γ produce different impacts. These impacts are summarized in table 1. At one extreme is a form of domestic price intervention in which the domestic price has no relationship to the level of world price; in this case, $\alpha > 0$ and $\gamma = 0$. This does not necessarily mean that the domestic price is set in an ad hoc manner, because the price may depend on domestic factors such as the balance of payments or inflation rate. What it does imply is that the particular country does not respond to world price signals and hence adds instability to the world market. This situation is analogous to that outlined by Josling where he points out that if all the countries in the market adopt this type of policy, then the world price in indeterminate, unless there is a storage policy.

It can be shown from equations (12) and (7) that if the level of α, or domestic price, is set in such a manner that it is higher than the world price, then the expected world price is lower than the free-trade world price. This result corresponds to the normal result from static trade analysis. The stability of world price, however, is less under this type of policy than it would be in the free market. Thus, in moving from a free trade policy to one in which a fixed domestic price is observed, the world price of the commodity is destabilized and the domestic price stabilized. This result is, in fact, identical to that presented in Just, Lutz, Schmitz, and Turnovsky, where they show the impact of price fixing on the stability of world prices.

Probably a more realistic case (case 2, table 1) is where the domestic price responds to changes in the world price, but the change in domestic price is less than the change in the world price. In this case α is positive and γ is between zero and one. Under this situation, it can be seen that the world price is less stable than in the free market case but more stable than where domestic prices are exogenously determined. The domestic price would not be perfectly stable, but would be more stable than either the free market price or the world price of the commodity. It can be seen that as the value of γ (the change in domestic price that results from a unit change in the world price) increases, the world price becomes more stable and the domestic price less stable. A γ value of one is the equivalent of the free trade situation and, in this case, the domestic policy has no effect on stability (case 3). As the γ coefficient increases above unity, the domestic policy adds to world price stability at the expense of domestic stability (case 4).

The effects of alternative domestic policies on the expected value of world price are not as clear as the stability impacts, but it can be shown that if the α and γ parameters are such that the expected domestic price is greater than the free market price, then the expected world market price is lower than the free market price.

Of the situations shown in table 1 and outlined above, the most probable case is that where domestic prices are less responsive than world prices but are still dependent on world prices. The desire for less responsive domestic prices could of course arise from attempts to stabilize consumer prices or from attempts to maintain a constant level of transfer payments between producers and consumers within a country.

Table 1. Summary of Impacts of Alternative Price Intervention Rules

	Free Market	Price Intervention			
	$PD = PW$ $\alpha = 0$ $\gamma = 1$	Case 1 $\alpha > 0$ $\gamma = 0$	Case 2 $\alpha > 0$ $0 < \gamma < 1$	Case 3 $\alpha > 0$ $\gamma = 1$	Case 4 $\alpha > 0$ $\gamma > 1$
$E(PW)$	$\frac{e - g + a - c}{d + b + f + h}$	$\frac{e - g + u - c - \alpha(f + h)}{d + b}$	$\frac{e - g + a - c - \alpha(f + h)}{d + b + \gamma(f + h)}$	$\frac{e - g + a - c - \alpha(f + h)}{d + b + f + h}$	$\frac{e - g + a - c - \alpha(f + h)}{d + b + \gamma(f + h)}$
$\mathrm{Var}(PW)$	$\frac{\sigma_1^2 + \sigma_2^2}{(d + b + f + h)^2}$	$\frac{\sigma_1^2 + \sigma_2^2}{(d + b)^2}$	$\frac{\sigma_1^2 + \sigma_2^2}{[d + b + \gamma(f + h)]^2}$	$\frac{\sigma_1^2 + \sigma_2^2}{(d + b + f + h)^2}$	$\frac{\sigma_1^2 + \sigma_2^2}{[d + b + \gamma(f + h)]^2}$
$\mathrm{Var}(PD)$	$\mathrm{Var}(PW)$	0	$\gamma^2\mathrm{Var}(PW)$	$\mathrm{Var}(PW)$	$\gamma^2\mathrm{Var}(PW)$
Magnitude c.f. free market					
$E(PW)$	—	$<FM$	$<FM$	$<FM$	$<FM$
$\mathrm{Var}(PW)$	—	$>FM$	$>FM$	=	$<FM$
$\mathrm{Var}(DP)$	—	$<FM$	$<FM$	=	$>FM$

Domestic Policies and Storage Policies

Because the likely form of domestic policy (case 2, table 1) tends to destabilize world markets, it seems logical to include in the above model an international storage policy which could be used to offset the destabilizing effects of the domestic pricing policy in the importing country.

Equation (15) represents a simple storage policy which states that the change in stocks depends only on the price level,

$$(15)\qquad DS_t - DS_{t-1} = \theta - \delta PW_t,$$

where, DS_t is the level of closing stocks and DS_{t-1} is the level of carry-in stocks. The expected price [equation (17)] along with domestic price intervention in the importing country can be determined from equation (16). Then,

$$(16)\quad SE_t - DE_t + DS_{t-1} = DI_t - SI_t - DS_t,$$

$$(17)\quad E(PW) = \frac{e - g + a - c - \alpha(f + h) + \theta}{d + b + \gamma(f + h) + \delta}.$$

The variance of world price and domestic price are, respectively,

$$(18)\quad \mathrm{Var}(PW) = \frac{\sigma_1^2 + \sigma_2^2}{[d + b + \gamma(f + h) + \delta]^2}, \text{ and}$$

$$(19)\qquad \mathrm{Var}(PD) = \gamma^2\,\mathrm{Var}(PW).$$

By comparing the above relationships with the free trade situation (6), (7), and (8), it is possible to show the conditions that are necessary to retain free market levels of expected price and price stability with the existence of both domestic policy intervention and buffer stock policies. Free-trade price stability can be retained by using a storage response parameter,

$$(20)\qquad \delta = (f + h)\,(1 - \gamma).$$

It should be noted that the world price would become more stable than the free market if δ were increased above this level. Equation (18) shows that as δ is increased the variance of the world price will decrease.

The expected value of world price can be retained at its free market level by adjusting the intercept term in the storage rule such that[1]

$$(21)\qquad \theta = (f + h)\,\alpha.$$

The fact that such a storage rule can be found in a linear model is not surprising. The most interesting implications of this analysis are obtained in considering the allocation of costs for a storage program.

Studies which have considered cost sharing for international reserve schemes usually have used the level of consumption or imports as a basis for allocating costs (United Nations). But consider the importing region in this example that has a domestic policy which aims to stabilize and increase the level of domestic prices, thereby causing world prices to fall and become less stable. If the level of consumption or imports are the basis for cost allocation, the institution of such a policy will cause the country's relative costs to decrease as consumption and imports have been reduced, even though it has added instability to the market. This apparent inconsistency shows that in cases where a country uses domestic agricultural policies that destabilize the international market, allocation of costs of a storage program should not be based on its relative consumption level but rather on the cost of providing a reserve program that would offset the international impacts of its policy. The costs of storage, which would be an increasing function of the expected level, and variance of the stock should increase as the domestic policy becomes more disruptive.

This form of cost allocation could have impacts on the form and level of domestic intervention. Normally the major considerations involved in determining the level of internal policy are the welfare costs and transfers within the economy, while international effects are ignored, especially in smaller countries. Cost allocation of the type suggested would ensure that a country paid for the international impacts of its domestic policies and could lead to lower levels of domestic intervention or at least consideration of international programs which could replace domestic programs. Although the problem of cost allocation is not developed further, the following section attempts to measure the impacts of buffer stocks and domestic policy changes on the world wheat market to provide a measure of the size and importance of domestic pricing policies.

[1] It should be noted that this is a short-run adjustment because a change in θ implies a new equilibrium, or expected price level, which would require an adjustment in the supply function to ensure that expected stocks are constant.

An Empirical Model

A seventeen-region stochastic simulation model of the world wheat sector is used to simulate, first, a base scenario of prices and trade flows for the future assuming a continuation of existing domestic policies; second, a buffer stock policy which could be used to stabilize the world market; and third, the impacts of making domestic wheat-pricing policies more responsive to changes in the world price of wheat.

The Simulation Model

The econometric simulation model used in this analysis has been developed and used in a more comprehensive analysis of international buffer stock policies (Zwart). Although it is a relatively large model, the structure is kept fairly simple by estimating derived demand and supply functions. These relationships, which include effects of domestic pricing policies, are equivalent to the S^*S^* and D^*D^* curves in figure 1 or, algebraically, equations (10) and (11). Because of the derived nature of the relationships, the independent variables used in the estimation include the world price of wheat, normal supply and demand shifters, as well as variables which attempt to account for changes in the price intervention relationships. Such variables include the gross national product (GNP) and international financial reserves of each region. To account for existing domestic storage policies in the wheat market, demand for stock functions are estimated for the major exporting regions to summarize the relationships between their domestic stock levels, production levels, and the world price. The presence of these stockholding relationships and the lagged price response in the derived supply functions make the model recursive and allow simulation over time. The residuals from the econometrically estimated supply and demand relationships are used to generate pseudo-random error terms (McCarthy). Use of these random error terms in the model, and replication over time, allows stochastic simulation of the variables in the wheat market. The values of the endogenous variables, which result from the simulations, are expressed in terms of their expected values as well as their distribution for any period, thereby accounting for the variability that arises from yield fluctuations and shocks in domestic policies which influence demand levels.

Appendix 1 contains the econometric estimates of the derived supply, derived demand, and the demand for stock functions, along with a description of the variables and regions included in the model. Validation results are not given in this study, but a full historical validation is presented in Zwart.

A comparison between the derived demand and supply elasticities estimated in this study and Rojko, Urban, and Naive's estimates of domestic elasticities suggests that domestic policies are indeed destabilizing in the world market, because the derived estimates are more inelastic than the domestic estimates (table 2).

The Base Simulation

To provide a base or status quo simulation, the exogenous variables in the model were forecast from 1976/77 to 1990/91 and used to simulate conditions in the world wheat market over this period. Because the estimated derived demand and supply functions are used in this simulation, the assumption that domestic agricultural policies remain in their current form is implicit. In the same manner, it is assumed that domestic wheat storage policies in the major exporting regions remain as they have in the past, but because simulated stock levels could get extremely low or negative in some

Table 2. Derived Demand and Domestic Demand Elasticities

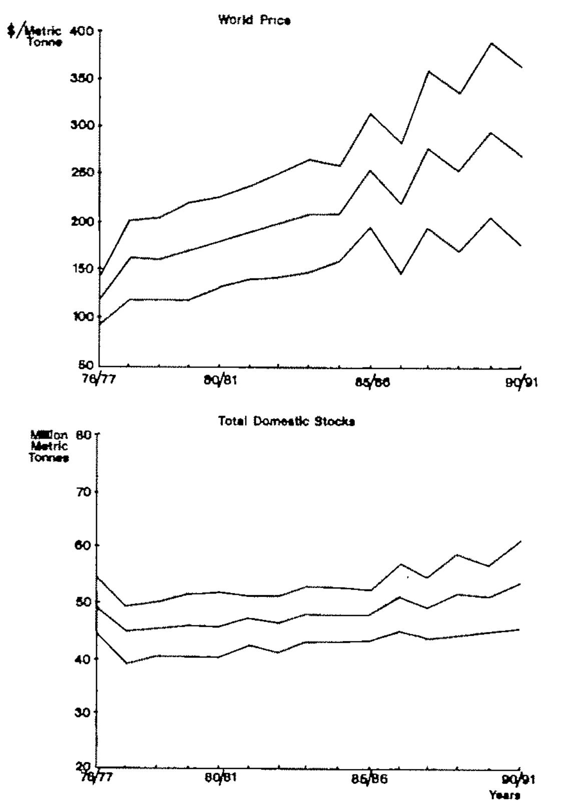
	Derived Demand[a]	Domestic Demand[b]
United States	−.10	−.2
Canada	0	−.2
Australia	0	−.1
Argentina	0	−.3
Japan	−.093	−.33
Brazil	−.10	−.2
India	0	−.5
Pakistan	0	−.5
Egypt	0	−.2
EEC	−.0004	−.3
East Europe	0	−.2
West Europe	−.053	−.3
Other Asia	−.15	−.2
Other Africa	−.085	−.2
Other America	0	−.25
USSR	0	−.2
China	0	−.1

[a] From the relationships estimated in this study (appendix 1).
[b] Estimated from Rojko, Urban, and Naive.

periods, minimum working stock constraints were included in the model. These constraints simply state that domestic wheat stocks have minimum levels in each region which are a fixed proportion of current production in that region.

Figure 2 shows the time paths of two endogenous variables in the model. In each graph the middle line represents the expected value of the variable and the outer two lines represent one standard deviation each side of that expected value. These distributions were derived from fifty replications of the fifteen-year period, and show the stochastic nature of the variables in each year.

It can be seen that the expected value of the world price follows a slight upward trend in the early years of the simulation, but becomes unstable after 1980. The same instability is reflected in changes in world stocks, and is caused by the fact that in these periods the domestic stock levels were constrained by the minimum working stock requirements. Normally constraints such as these would not make a model unstable, but in this case it can be shown that without price-responsive demand for stock functions, the model displays the characteristics of an unstable cobweb.[2] This result shows the importance of buffer stock policies in the world wheat market, given the inelastic nature of the derived demand relationships.



F-2 Time paths of selected endogenous variables in status quo simulation

Figure 2.

A further implication of this experiment is that these types of domestic policies can exist only in the presence of price-responsive national stock policies which remove the unstable cobweb effect. In fact, the development of these rigid domestic pricing policies is probably the result of the existence of the large stocks over the estimation period (1953–74).

Table 3 shows the mean expected values and standard deviations of selected regional and summary variables over the simulation period. The standard deviations presented do not measure the variance of the individual variable over time; but rather, they measure the mean of the within-year standard deviations, i.e., the average width of the bands shown in figure 2.

Value of trade is used as a measure of the financial implications of policy changes in the individual regions. Normally consumer and producer surplus would be the measures used, but the use of derived rather than domestic supply and demand functions makes this impossible. The value of trade measure does, however, show the net impact of policy changes on the trade balance of each particular region and provides an aggregate measure of financial implications. The results presented in table 3 provide the base with which the following policy experiments can be compared.

A Buffer Stock Policy

To show the stabilizing impacts of a buffer stock policy on the world wheat market, a simple price-responsive storage rule is included in the stochastic simulation model. It is assumed that the stock is held by an international authority which has an initial wheat stock at the beginning of the 1976/77 crop year of 40 million metric tonnes and that domestic stocks consist only of working stocks as defined previously.

[2] The general conditions for such a model are that the sum of the lagged price response coefficients in the supply functions exceed the sum of the price response coefficients in the demand curves (Waugh).

Table 3. Base Simulation 1976/77–1990/91, and Changes Resulting from Alternative Policies

	Base Simulation	Buffer Stock Policy	Changing Domestic Policies
World price ($US/tonne)	211.95	.60	−31.4
	(59.18)	(−88.40)	(−89.4)
Total supply (mmt)	456.59	.05	−3.9
	(15.09)	(−26.80)	(−27.6)
Total consumption (mmt)	456.09	−.03	−3.9
	(11.45)	(−10.40)	(−9.2)
United States			
Supply (mmt)	55.3	.5	−3.7
	(3.8)	(−13.9)	(−13.3)
Consumption (mmt)	23.4	−.1	−5.5
	(2.0)	(−45.9)	(−43.4)
Value of trade ($US mill.)	7085	.2	−35.4
	(2520)	(−76.0)	(−80.0)
Canada			
Supply (mmt)	19.2	.9	−1.5
	(3.1)	(−.6)	(−1.6)
Consumption (mmt)	5.2	0	−5.0
	(.4)	(0)	(0)
Value of trade ($US mill.)	2926	1.5	−32.4
	(938)	(−49.8)	(−80.0)
Japan			
Supply (mmt)	.9	−3.2	−24.7
	(.6)	(−17.9)	(0)
Consumption (mmt)	6.7	−.2	−.9
	(.4)	(−48.8)	(−34.9)
Value of trade ($US mill.)	−1201	2.8[a]	−27.9[a]
	(284)	(−58.8)	(−70.0)
India			
Supply (mmt)	36.8	0	0
	(1.2)	(0)	(0)
Consumption (mmt)	40.8	0	−10.2
	(1.1)	(0)	(−4.6)
Value of trade ($US mill.)	−939	2.3[a]	[b]
	(552)	(−30.2)	(−55.8)
EEC (9)			
Supply (mmt)	53.2	−.1	−4.9
	(3.2)	(−33.2)	(−33.2)
Consumption (mmt)	48.8	0	−7.2
	(1.0)	(0)	(−9.3)
Value of trade ($US mill.)	894	19.0	−6.5
	(454)	(−6.0)	(−44.5)

Note: Policy results are expressed as percentage changes from base, standard deviations and changes in standard deviations appear in parentheses beneath expected values.
[a] Percentage change in cost of imports.
[b] India switched from an importing to exporting region (−$939 mill. to $44 mill.).

The general form of the storage rule is as follows:

$$DS_t = \theta - \delta PW_t + \beta T., \tag{22}$$

where, DS_t is the closing level of world stocks in period t; PW_t is the world price of wheat; and $\beta T.$ is an intercept shift factor where T is the time period.

This simple storage rule is similar to that developed in the previous section, but it is necessary to include the intercept shift factor to account for the long-run trends in the exogenous variables over time. Without this factor the tendency for price to increase over time would cause stocks to decrease. In this experiment the value of 'δ' is arbitrarily set equal to 2.5, which represents the change in wheat stocks per unit change in the world price.[3] The 'θ' and 'β' parameters were calculated from the growth and price levels in the base simula-

[3] A δ value of 2.5 implies an elasticity of stock level changes with respect to the world price of −11.0 at mean values over the simulation period.

tion in an attempt to maintain an expected world stock level of 40 million tonnes.

The summary results presented in table 3 indicate that the buffer stock policy can have a substantial impact on the stability of the world wheat market. Although the level of price, total production, and total consumption are not greatly affected by the policy, the stability of these variables is increased considerably. For example, the expected value of the world price is increased only marginally from \$211.9/tonne to \$213.32/tonne, but the standard deviation of the price is reduced from \$59.18/tonne to \$6.88/tonne. The stability gains for consumption and production are not as great.

In order to attain this level of stability the standard deviation of the stocks in the buffer was 17.2 million tonnes. This suggests that it would be necessary to have a high level of expected stock to minimize the probability of completely depleting stocks.

The costs associated with running the buffer stock are measured in two ways: first, there is a storage cost which reflects the physical cost of storing grain and the interest cost of the capital involved in the grain stored;[4] second, the profit of the buffer stock agency measures the trading profit or loss from buying and selling wheat. The average cost of storage for the buffer stock is \$596 million per year with a standard deviation of \$333 million per year, and the buffer stock would run at an expected loss of \$172 million per year with a standard deviation of \$1,423 million. The cause of the trading loss of the agency is the fact that the average level of buffer stock decreases in the early years when prices are relatively low and increases in the later part of the simulation period when prices are higher. Thus, the expected level of stocks increases over time. This increase is a result of the simple form of the intercept shift term in the stock demand function [equation (22)]. If this exogenous shift factor had been specified more accurately such that the expected stock level remained constant over time, then the expected profit of the agency would have been positive.

The loss of the stock agency is reflected in the difference between the value of the exports and imports. Because the agency paid more for the stocks it purchased than it received in sales, there is a transfer of revenue to the exporting regions and an increased cost to the importing regions. Because of this transfer, it is difficult to define accurately the change in the total value of trade which can be attributed to the buffer stock policy, but it would appear to be in the order of a 1%–3% increase. This change is obviously very small and confirms the results presented in Zwart and Meilke.

Table 3 also shows the impact of the buffer stock policy on a subset of the regions within the model. There is little impact on the expected value of the variables in each region, especially in terms of supply and consumption. The changes in the expected trade values are again due to the tendency for stocks to accumulate over time, which causes the world price to be above the base level in the later periods of the simulation. Thus, regions that show a strong trend in the level of trade over time have greater changes in trade values. For example, in the simulation, India shows a decreasing dependence on trade over time, which reduces the cost of imports relative to the base; conversely, the EEC region shows increasing exports over time, thereby increasing the value of exports.

The major impacts of the buffer stock simulation are seen in the reductions of instability. The reduction in the standard deviations of supply and demand vary considerably between regions, depending on the relative price responsiveness of the derived supply and demand functions. Thus, regions that have relatively price-flexible policies, such as the United States, tend to gain the most stability from the program. The gain in the stability of trade values affects all regions, but the degree of benefit depends on many factors, such as the size and importance of that region in world trade. It should be noted that the increased stability of trade values is reflected somewhat in the unstable profit or loss of the buffer stock authority. Although the individual regions have been able to stabilize trade values the Authority must accept a standard deviation of costs of \$1,423 million.

In summary, it can be seen that the presence of a price responsive buffer stock in the world wheat market adds considerable stability to price, production, consumption, and the value of trade, with marginal impacts on the expected values of these variables. The major impacts on the expected values of these variables arise from the ability of the Authority to

[4] The physical storage cost was assumed to be \$5.50 per tonne, and the interest rate used was 7%. The quantities on which these costs were based was the average of the opening and closing stocks for each crop year.

predict exogenous shifts in the market which should not be stabilized (for example, the long-run trend in world prices). Although the expected costs of the program do not appear to be excessive, it should be remembered that these costs are extremely variable and would have to be shared between the participating countries. The net impact of such a policy appears to be that of transfering instability in prices and consumption, from individual countries to unstable financial requirements in an International Buffer Stock Authority, with the added difficulty that misspecification of the storage rule by the Authority can result in revenue transfers between importing and exporting countries and the Stock Authority.

As an alternative to a buffer stock scheme, the following section considers the impacts of modifying domestic pricing policies to absorb instability in the world market. Although the simulation is hypothetical, it does provide a measure of the importance of current domestic policies.

Changing Domestic Pricing Policies

In the first part of this paper it was shown that the manner in which governments change domestic prices in response to world price changes can have an impact on the stability and level of world prices. To simulate the effects of more responsive policies, an experiment is conducted in which it is assumed that consumer prices in individual countries directly reflect world price changes.

The derived demand curves in the simulation model are modified by changing their slopes to approximate the true consumer demand elasticity in each region. Rojko, Urban, and Naive's estimates of consumer demand elasticities (table 2) are used as a measure of the true elasticity. The slopes of the derived demand functions are changed in such a manner that these elasticities hold at the 1976/77 expected prices and quantities from the base solution. The coefficients on the exogenous shifters and the random errors are assumed to remain the same as in the derived demand functions, but the intercept terms in the linear functions are changed to accommodate the modified slopes.

It is tempting to call this simulation a "free trade" situation, but this is not true because the degree of absolute protection has been retained in each region and the derived demand curves are merely rotated around the 1976/77 equilibrium prices and quantities.[5] For simplicity in analyzing the results, it has been assumed that only consumer pricing policies are changed and that the derived supply functions for each region are retained. Obviously a fully flexible pricing system would assume that producer prices in each region also reflect world price changes. Domestic storage policies in the major exporting regions are assumed to be the same as in the base simulation and there is no international buffer stock.

Table 3 shows the results of the simulation experiment. It can be seen that the change in domestic policies has a considerable impact on the stability and level of the world price. The increased slope of the derived demand functions has reduced the standard deviation of the world price to $6.25 per tonne, which is approximately the same degree of stability as was attained with the buffer stock policy. The expected value of price over the simulation period is, however, considerably lower than in either the base or the buffer stock simulation. This reduction in the level of price is associated with the lower level of consumption that results from the increased elasticity of the demand functions. The price level is the same as in the base simulation for the first time period of the simulation, but as supply and demand shift to the right over time, consumption and price are lower than with a more inelastic response.

This result is caused by the fact that an elastic demand curve shifting to the right against a supply curve will result in a lower price level over time than an inelastic demand curve shifting by the same amount. The implication is that a lack of domestic price response will influence not only the short-run, but also the long-run, stability of world prices.

The lower average level of price has a considerable impact on the expected value of trade, but causes only minor reductions in the levels of consumption and production. Total production and consumption is marginally more stable with the domestic policy changes than it is with the buffer stock, but the gain in consumption stability is less than the gain in production stability. This was expected as the

[5] The implicit assumption in selecting 1976/77 level of prices and quantities is that the absolute protection from that period is retained in the simulation. While these levels are possibly not representative of the past they provide a current base.

increased slope of the demand functions should result in more variable consumption, but the effect is counteracted by the degree of price stability that is attained.

The individual region results give an indication of the range of impacts. As the derived supply relationships have not changed in this simulation, the magnitudes of the supply effects depend on the degree of price response in the estimated functions. More price-responsive regions have a greater reduction in the expected level of supply, but also have increased supply stability. The magnitude of the consumption changes depend on the relative magnitudes of the derived demand elasticity and the assumed domestic elasticity. For example, in India, which has a perfectly inelastic derived demand curve and yet an elastic domestic demand curve, there is a 10% decrease in the expected level of consumption and a relatively small reduction in the standard deviation. In contrast, the magnitudes of the elasticities, which are similar in the United States, result in a smaller drop in expected consumption and larger stability gains.

The greatest impacts of this policy experiment are seen in the value of trade. The lower world price level results in a substantial decrease in the value of trade which is obviously to the benefit of importing regions and to the detriment of exporting countries. In fact, the lower price in this simulation reduced imports by India to such an extent that the region became a marginal net exporter of wheat over this period. Because of the increased price stability, there are substantial reductions in the standard deviations of trade values in each region. This stability increase is greater than that for the buffer stock policy and is more evenly distributed between regions.

The simulation results presented above have shown that the adoption of more flexible consumer pricing policies would add considerable stability to the world wheat market, but could result in constrained consumption as the long-run wheat price increases. In fact, the gains in stability from modifying consumer pricing policies are greater than could be attained from the buffer stock policy. Under the assumption that the derived demand elasticities from the econometric model and the external estimates of domestic demand elasticities are valid, it can be seen that domestic pricing policies have imposed a very high degree of instability on the world wheat market.

Conclusions

The theoretical model and simulation experiments presented in this paper have shown the importance of domestic wheat pricing policies in determining world price stability. The inelastic nature of the estimated derived supply and demand functions imply that many countries have attempted to insulate their domestic wheat markets from shocks in the world market. The insulating effect of these policies means that small shocks in world supply or demand are exaggerated because domestic supply and demand levels do not respond to their fullest extent.

An international buffer stock would reduce the instability of price and foreign exchange earnings, but would have large and unstable financial requirements. Unless the storage rule is carefully specified, a long-run increase or decrease in stocks could cause revenue transfers between importing and exporting regions. As an alternative to an international buffer stock policy, changing domestic pricing policies was shown to produce a similar degree of price and exchange stability. It is extremely difficult to state which of these policy alternatives would be the most appropriate. The major difficulty arises in determining the precise objectives which must be met. These involve not only international, but also domestic policy objectives which must trade off factors such as increased price stability with the stability and level of consumption. While factors such as level and stability of consumption may be relatively unimportant in developed countries, they are obviously of vital importance in countries such as India.

To better evaluate these problems, it is necessary for researchers to determine the relationships between world markets and individual domestic policies. These should be measured not only in terms of the absolute protection, but also the longer-run stability impacts which would require more knowledge of the dynamics and causal relationships in government decision making. There have been considerable advances into the normative aspects of these decisions, but there should also be consideration of the positive relationship to enable better predictions or analysis of future policy changes.

[*Received November 1977, revision accepted March 1979.*]

References

Bieri, J., and A. Schmitz. "Export Instability, Monopoly Power, and Welfare." *J. Int. Econ.* 3(1973):389–96.

Grennes, T., P. R. Johnson, and M. Thursby. "Insulating Trade Policies, Inventories, and Wheat Price Stability." *Amer. J. Agr. Econ.* 60(1978):132–34.

International Monetary Fund. *International Financial Statistics.* Washington, D.C., various dates.

International Wheat Council. *World Wheat Statistics.* London, various issues.

Johnson, D. G. "World Agriculture, Commodity Policy, and Price Variability." *Amer. J. Agr. Econ.* 57(1975):823–28.

Josling, T. E. "Government Price Policies and the Structure of International Agricultural Trade." *J. Agr. Econ.* 28(1977):261–78.

Just, R. E. "Theoretical and Empirical Possibilities for Determining the Distribution of Welfare Gains from Stabilization." *Amer. J. Agr. Econ.* 59(1977):912–17.

Just, R. E., E. Lutz, A. Schmitz, and S. Turnovsky. "The Distribution of Welfare Gains from International Price Stability under Distortions." *Amer. J. Agr. Econ.* 59(1977):652–61.

Konandreas, P. A., and A. Schmitz. "Welfare Implications of Grain Price Stabilization: Some Empirical Evidence for the United States." *Amer. J. Agr. Econ.* 60(1978):74–84.

Lattimore, R. G. "An Econometric Model of the Brazilian Beef Economy." Ph.D. thesis, Purdue University, 1974.

McCarthy, M. D. "Some Notes on the Generation of Pseudo Structural Errors for Use in Stochastic Simulation Studies." *Econometric Models of Cyclical Behavior,* ed. B. Hickman, pp. 185–91. New York: Columbia University Press, 1972.

Rojko, A. S., F. S. Urban, and J. J. Naive. *World Demand Prospects for Grain in 1980 with Emphasis on Trade by Less Developed Countries.* USDA ERS For. Agr. Econ. Rep. 75, 1971.

Shei, S. Y., and R. L. Thompson. "The Impact of Trade Restrictions on Price Stability in the World Wheat Market." *Amer. J. Agr. Econ.* 59(1977):629–38.

Waugh, F. V. "Cobweb Models." *J. Farm Econ.* 46(1964):732–50.

Zwart, A. C. "An Empirical Analysis of Alternative Stabilization Policies for the World Wheat Sector." Ph.D. thesis, University of Guelph, 1977.

Zwart, A. C., and K. D. Meilke. *Economic Implications of International Wheat Reserves.* School of Agr. Econ. and Ext. Ed. Disc. Paper No. 1, University of Guelph, June 1976.

Appendix I

Variable Definitions and Estimated Relationships

Variable Definitions:

- PW_t World price of wheat defined as the export price of U.S. hard winter ordinary, fob Gulf ($US/metric tonne, July/June year).
- QS_{it} Quantity of wheat produced in region i in period t (million metric tonnes (mmt), July/June year).
- QD_{it} Quantity of wheat produced in region i in period t calculated from production, trade, and stock data for a July/June year, mmt.
- DS_{it} Closing level of wheat stocks in the individual stockholding countries at 1 July, mmt.
- Π_{it} Exchange rate in region i in period t (domestic currency/$U.S., 1 Jan. spot rate).
- R_{it} International financial reserve holdings in region i at the close of calendar year t. ($US million, 31 Dec.).
- Y_{it} Level of national income in region i in period t measured as gross national product (millions local currency, calendar years).
- N_{it} Population in region i in period t (millions, midyear).
- T Time variable (1947 = 1, 1976 = 30).

Dummy Variables:

Canada supply—Dummy variable reflects the impact of the LIFT program (1970/71 = 1, otherwise 0),

India supply—Represents the impact of the green revolution on India. There is both an intercept dummy and a time dummy variable: (1947/48–1967/68 = 0, 1968/69 . . . = 1), (1947/48–1967/68 = 0, 1968/69 . . . = T).

EEC supply and demand—Reflects the formation of the C.A.P.: (1947/48–1962/63 = 0, 1963/64, . . . , = 1).

Pakistan demand—Reflects the formation of Bangladesh: (1947/48–1971/72 = 0, 1972/73, . . . , = 1).

U.S. stock demand—Reflects the change in the U.S. storage policy when the loan rate was decreased: (1947/48–1964/65 = 1, 1965/66, . . . , = 0).

Data: Regression results presented here were estimated using data from crop year 1953 to 1974 unless otherwise specified. Data were obtained from the International Wheat Council, *World Wheat Statistics* and the International Monetary Fund, *International Financial Statistics.*

Appendix Table 1. Derived Supply Functions

	Price$(t-1)$	Supply$(t-1)$	Stock$(t-1)$	Time	Dummy	Intercept	R^2	D.W.[e]
	$\pi_{t-1} \cdot PW_{t-1}$	QS_{t-1}	DS_{t-1}	T				
United States	.029		−.23	.66		27.57	.74	1.83
	(.86)[a]		(−2.31)	(5.93)				
Canada			−.38	.18	−2.33	18.09	.19	1.22
			(−1.93)	(1.65)	(−.53)			
Australia	.017			.33		1.27	.48	2.04
	(.57)			(4.73)				
Argentina				−.0081		6.66	0	1.62
				(−.16)				
Japan	.000003	.91				−.031	.69	2.30
	(.33)	(7.02)						(.94)
Brazil	.00001	.84				.14	.44	1.91
	(.266)	(4.35)						(.61)
India			.94[b]	.31	−15.07	5.51	.94	1.32
			(3.21)	(3.79)	(−2.09)			
Pakistan	.00026	.47		.11		.46	.86	1.93
	(.61)	(2.68)		(3.24)				(.16)
Egypt	.0055	.34				.83	.20	2.17
	(1.51)	(1.62)						(n.a.)
USSR[c]				2.23		35.15	.47	2.63
				(4.08)				
China[d]	.049			.43		10.60	.85	1.75
	(4.03)			(4.24)				
EEC (9)	.043			.74	1.41	15.66	.87	2.77
	(2.26)			(5.28)	(.76)			
Eastern Europe	.022	.43		.46		.42	.92	2.29
	(1.37)	(2.16)		(3.35)				(.94)
Western Europe	.022	.77				1.56	.55	2.38
	(1.73)	(5.16)						(1.31)
Outside Asia	.0077	.81				3.11	.68	2.28
	(.48)	(6.93)						(.81)
Outside Africa				.17		2.02	.65	1.02
				(6.5)				
Outside America	.0065	.60		.017		.72	.59	1.84
	(1.90)	(2.79)		(.96)				(n.a.)

[a] Values in parentheses are t statistics.
[b] This coefficient relates to a time trend dummy variable (see variable definitions).
[c] Estimated using data from crop years 1957/58 to 1974/75.
[d] Estimated using data from crop years 1962/63 to 1974/75.
[e] Values in parentheses under Durbin-Watson statistics are h-statistics.

Appendix Table 2. Derived Demand Functions

	Price	Income	Population	International Reserves	Dummy	Intercept	R^2	D.W.
	$\pi \cdot P\dot{W}$	Y	N	R				
United States	−.026 (−2.48)[a]	6.84 (4.90)				−24.23	.51	2.4
Canada		.58 (2.80)				1.93	.24	1.91
Australia		.85 (6.72)				.42	.67	1.30
Argentina			.19 (3.08)			−.13	.28	2.76
Japan	−.000017 (−1.45)		.12 (10.37)	.0000026 (.11)		−6.38	.93	2.04
Brazil	−.00054 (−1.33)	.94 (3.04)		.00022 (1.84)		−8.11	.79	1.78
India			.096 (19.80)	.00084 (1.37)		−28.74	.96	1.82
Pakistan			.13 (17.47)	.0036 (3.12)	7.10 (19.40)	−8.53	.95	1.66
Egypt			.20 (14.67)			−2.52	.91	1.52
USSR[b]			.87 (5.55)			−121.81	.63	2.11
China[c]			.038 (3.30)			.061	.45	1.18
EEC (9)	−.00021 (−.015)		.32 (5.25)		2.58 (−1.7)	38.76	.77	2.13
Eastern Europe			1.097 (20.06)			−88.58	.95	2.19
Western Europe	−.011 (−1.30)		.21 (5.77)			−5.63	.59	1.63
Other Asia	−.049 (−1.55)		.066 (3.15)	.00016 (.19)		−4.01	.96	1.30
Other Africa	−.0085 (−.93)		.052 (7.94)	.00027 (1.34)		−7.06	.94	1.38
Other America			.062 (24.78)			−1.97	.96	2.20

[a] Values in parentheses are t statistics.
[b] Estimated using data from crop year 1956/57–1973/74.
[c] Estimated using data from crop year 1961/62–1973/74.

Appendix Table 3. Demand for Stocks Functions

	Price	Stock ($t-1$)	Production	Availability	Dummy	Intercept	R^2	D.W.	Mean	C.O.V.
	$\pi \cdot PW$	DS_{t-1}	QS	$(QS + DS_{t-1})$						
United States	−.13 (−3.54)[a]	.47 (3.97)	.67 (3.13)		12.33 (4.38)	−9.15	.82	1.26 (2.16)[b]	23.67	15.75
Canada	−1.037 (−1.46)	.75 (3.33)	.57 (4.91)			−1.38	.61	1.26 (1.48)	17.05	15.6
Australia	−.016 (−.63)	.43 (3.17)	.55 (4.78)			−.54	.66	1.07 (2.92)	4.85	31.8
Argentina	−.0012 (−1.24)	.58 (1.08)	.15 (4.76)			−.57	.52	1.94 (.18)	3.59	23.82
EEC (9)	−.017 (−1.81)			.069 (1.80)		4.88	.13	2.33	6.32	16.83

[a] Values in parentheses are t-statistics.
[b] Numbers in parentheses are h-statistics.

Rural Household Savings Behavior in South Korea, 1962–76

K. N. Hyun, D. W Adams, and L. J. Hushak

This study documents the extent of savings in representative rural households in South Korea during 1962–76. A technique for measuring permanent income from cross-section data is used to estimate marginal savings behavior. The results show that households saved a remarkably large part of their incomes. During the late 1960s these savings were, on the margin, about one-fifth of permanent incomes and about four-fifths of transitory incomes. Authors also conclude that useful measures of permanent and transitory income can be estimated from cross-section data.

Key words: permanent income hypothesis, rural household savings, South Korea, voluntary savings.

Savings behavior in high income countries has drawn substantial attention from economists in the past several decades. Analysis of aggregate or urban household information in these countries has led to development of useful theories about savings behavior (Mikesell and Zinser). Only recently, however, have a small number of studies been done on rural household savings in low income countries (Adams). Lack of appropriate data has slowed this analysis and made it difficult for researchers to apply new theories, such as the permanent income hypothesis, to the analysis of rural savings behavior. Those interested in this topic have been forced to use fragmentary, cross-section information, often collected for some other purpose, to shed light on rural savings activities. Because of these data limitations, researchers also have been forced to relate savings behavior largely to current household income. The paucity of research on this topic has made it nearly impossible to confirm or dispel myths which pervade the development literature about rural savings behavior.

Research on rural savings in low income countries is further complicated by the adverse effects of many government policies on rural household incomes. These include concessionary interest rate policies, product and input prices, taxes, and foreign exchange regulations which result in low incomes and weak incentives to save in rural areas. It is impossible to answer directly questions about what savings behavior would have been in a country if policies had provided more income and stronger savings incentives in rural areas. Only indirect answers are possible. These are drawn from analysis of rural household savings performance in those few countries which have allowed rural incomes to grow substantially, and also have provided significant positive incentives and opportunities for rural households to save.

During the past dozen years, South Korea appears to have offered a positive environment for rural savers (see Ong, Adams, Singh on Taiwan). South Korea also has assembled rural household data through representative Farm Household Economy Surveys since 1962 which are rich enough in detail and also reliable enough to justify careful analysis of savings behavior (Hyun). A further advantage is that time series and cross-section data are available for the individual households.

In the following discussion we attempt to do two things. The first objective is to document the extent of voluntary rural household savings in South Korea among survey households 1962–76. The second objective is to test a technique recently suggested by several researchers for estimating permanent household income from cross-section data (Bhalla). If this technique proves to be reliable, it will allow more comprehensive analysis of savings

K. N. Hyun is an economist with the Korea Rural Economics Institute; D. W. Adams and L. J. Hushak are professors of agricultural economics at Ohio State University.

behavior in countries where only cross-section data are available.

Rural Household Incomes and Savings

The Korean economy as well as the agricultural sector have grown substantially since the early 1960s. Gross national product has increased by almost 10% per year since 1962 and per capita income in real terms has gone up nearly sixfold. Growth in the agricultural sector has been less spectacular but nonetheless impressive, given the very limited land resources in South Korea. The real value of agricultural output more than doubled from 1962 to 1976. Major financial market and foreign exchange reforms in 1965, and adjustments in pricing policies during the late 1960s and early 1970s have substantially improved farmers' incomes and their incentives to save (Brown).

As can be noted in table 1, average net real income of the Farm Economy Survey households increased two and one-half times from 1962 to 1976. In comparison with other more developed countries, however, rural incomes were still quite low throughout the period. In 1962, average rural farm household income was less than $600 per year. This only amounted to about $90 per capita. The substantial increase in income by 1976 raised household incomes to about $1,460 and per capita incomes to about $260. By international standards, these rural households are far from affluent.

Although not shown in table 1, about 20% of household income was provided by off-farm earnings throughout the period. Changes in weather and government pricing policies were important factors explaining major variations in incomes in the mid-1960s, the late 1960s, and early 1970s. As might be expected, household consumption expanded with household incomes, but at a slower rate. This resulted in sharp increases in gross household savings, especially after the mid-1960s. The average propensity to save jumped from only .15 in 1962 to .33 in 1976. Despite relatively low absolute levels of income, rural households in South Korea have saved large proportions of their incomes in the past few years.

Without complicated analysis, one can conclude that a major part of this increase in expressed savings resulted from the expansion in real household incomes. As Wai has pointed out, however, incentives and opportunities to save are important factors which help explain part of savings behavior. Friedman and others have argued that the quality of household income flows also may help to explain this behavior. Quality may be indicated by the stabil-

Table 1. Average Household Income, Consumption Expenditures, and Propensity to Save of Farm Economy Survey Households in Korea, 1962–76

Year	Households (Number)	Net Household Income (1)	Household[a] Consumption Expenditures (2)	Gross Savings (3) = (1) − (2)	Average Propensity to Save (4) = (3)/(1)
			(In 1970 Korean 1,000 Won)[b]		
1962	1,163	177	150	27	.15
1963	1,161	201	177	24	.12
1964	1,172	204	173	31	.15
1965	1,173	166	157	9	.05
1966	1,180	177	157	20	.12
1967	1,176	190	170	20	.11
1968	1,181	212	176	36	.17
1969	1,180	241	197	44	.18
1970	1,180	259	218	41	.16
1971	1,180	333	235	98	.29
1972	1,182	352	263	89	.25
1973	1,170	369	270	99	.27
1974	2,515	366	242	124	.34
1975	2,517	373	271	102	.27
1976	2,516	444	298	146	.33

Source: Republic of Korea, Ministry of Agriculture and Fisheries (MAF), *Report on the Results of Farm Household Economy Survey*, yearly reports from 1962 to 1976.
[a] Includes household payments for taxes and interest.
[b] Adjusted to 1970 prices using index of wholesale prices of Korea. In 1970 the average exchange rate of won for a U.S. dollar was 304.

ity of income flows or by measures of permanent and transitory components of the flows. Still other researchers argue that changing characteristics of the household itself may influence consumption-savings behavior.

The data used in this study do not include information which sheds much light on savings opportunities or incentives. Lee, Kim, and Adams have argued that improved access to financial savings facilities in agricultural cooperatives over the 1961–75 period was an important stimulant to voluntary rural savings in South Korea. The data do allow analysis of the effects on savings behavior of permanent income and various household characteristics.

Empirical Models

Friedman's permanent income hypothesis rests on several tenets (Friedman, pp. 25–31), one of which assumes that a consumer's measured (observed) income (Y) and consumption (C) in a particular period may be separated into transitory and permanent components, and that marginal and average propensities to consume out of permanent income are independent of the level of permanent income. A number of empirical tests of this hypothesis have shown that the marginal propensity to consume (*MPC*) out of transitory income is greater than zero, but less than *MPC* out of permanent income (Ferber).

Friedman has proposed that permanent consumption be assumed equal to measured consumption (C). Statistically, the permanent income hypothesis can be stated as

$$(1) \qquad C = b_1 Y + b_2 Y_p + e,$$

where b_1 is the *MPC* out of transitory income (Y_{tr}), the *MPC* out of permanent income (Y_p) is ($b_1 + b_2$), and e is the random error. Equation (1) is derived from

$$C = c_1 Y_{tr} + c_2 Y_p,$$
$$Y = Y_{tr} + Y_p,$$

and substitution for Y_{tr} to obtain

$$C = c_1(Y - Y_p) + c_2 Y_p,$$
$$= c_1 Y + (c_2 - c_1) Y_p,$$

where $b_1 = c_1$, and $b_2 = c_2 - c_1$.

Studies in low income countries suggest that other household characteristics and returns to investments also affect consumption-savings behavior (Snyder, Alamgir). Under the permanent income hypothesis, it is argued that additional variables affect the *MPC* out of permanent income (Friedman, p. 25). Assuming the relationship is linear,

$$(2) \quad b_2 = b_{20} + b_{21}LD + b_{22}SI + b_{23}RT + b_{24}LQ + b_{25}DP.$$

Substitution into the consumption function (1) gives

$$(3) \quad C = b_1 Y + b_{20} Y_p + b_{21}LD\, Y_p + b_{22}SI\, Y_p + b_{23}RT\, Y_p + b_{24}LQ\, Y_p + b_{25}DP\, Y_p + e,$$

where *LD* is hectares of cultivated land area, *SI* is the ratio of gross farm income to gross household income, *RT* is the rate of return to capital during the previous year, *LQ* is the value of liquid assets, and *DP* is the ratio of dependents to total family members. (Detailed definitions of the variables are presented in the appendix.) Equation (2) describing the parameter variation is assumed to be nonstochastic.

Farm size (*LD*) is used as a proxy for farm investment opportunities. The coefficient b_{21} is expected to be negative (Kelly and Williamson). The source of income ratio (*SI*) indirectly influences consumer behavior through investment opportunities, relative stabilities of various income flows, prices of industrial goods, and demonstration effects of urban consumption patterns (Adams, Canh, Chin 1975). It is expected that multiple sources of income result in more stable incomes and the coefficient b_{22} is expected to be negative.

The rate of return to capital (*RT*) is used as a proxy for the profitability of all household investments. This variable also serves as the opportunity cost of current consumption versus future consumption. Theoretically, farmers who have high expected rates of return on capital will increase their investment in farm capital and also switch more of their current income to savings (Adams, Canh, Chin 1975). The relationship between the return to capital and *MPC* (b_{23}) depends on the source of the investment funds. If funds come from reduced consumption, the expected sign is negative. On the other hand, if funds come from increased borrowings or liquidating other assets to make investments, a positive relationship is expected.

The value of liquid asset holdings (*LQ*) is a rough measure of wealth. Several empirical studies have suggested that liquid assets are important factors affecting savings behavior (for example, Mizoguchi). The coefficient b_{24}

is expected to be positive. The dependency ratio (DP) is a measure of the proportion of household members who do not contribute to household income. The coefficient b_{25} is expected to be positive because a higher DP increases consumption without changing income (Leff).

Measurement of Permanent Income

From an empirical point of view, the permanent income hypothesis is difficult to test because of the measurement problem (Snyder). In this study, two different measures of permanent income are used: predicted income from an income-estimating function and a weighted average of past observed incomes. Bhalla recently used an "earnings function" to estimate the impact which permanent household characteristics have on the earnings of rural households in India. His analysis builds on earlier earnings function work by Gordon, Lilliard, and others. Following Bhalla, it is hypothesized that various permanent household characteristics, which have been used for tests of the permanent income hypothesis, explain permanent income through a functional relationship. Under this hypothesis, permanent income can be estimated with the statistical model

$$(4) \quad Y = c_0 + c_1LD + c_2LQ + c_3ED + c_4FM + c_5DP + c_6SI + u,$$

where ED is average years of schooling of household members more than six years of age, FM is family size, and other variables are as defined previously. The predicted values of income ($\hat{Y}$) are the values of permanent income for each household, and the residuals ($\hat{u}$) are the values of transitory income.

The advantage of this technique is that it can be estimated from cross-section data for a single year.[1] The disadvantage is that it cannot account for cyclical changes which cause the total sample to deviate uniformly from expected income. However, if the explanatory variables in equation (4) measure the human and physical resources of households, the predicted incomes at least will reflect the relative permanent income status of households in the sample and can be used as measures of permanent income in consumption function estimation.

The second method of measuring permanent income is a weighted average of measured incomes for the most recent three years, including the year considered. As Friedman suggested, permanent income is usually measured by a weighted average of current and past values of measured incomes with weights declining exponentially. This method, however, requires fairly long time-series data. With only three years of income data available for this study, the weights were arbitrarily designated, and permanent incomes calculated as follows:

$$(5) \qquad Y_p = .5Y + .3Y_{-1} + .2Y_{-2},$$

where subscripts are numbers for lagged years.[2]

Results of Model Estimation

The data used in the analysis come from panel households in the Korean Farm Household Economy Survey. There were 131 households which were surveyed each year 1968 through 1970. Analysis of this panel data for 1970 make up the main body of this section. The data for 1968 and 1969 are used only for calculating permanent income as specified by equation (5), the second measure of permanent income, and the rate of return on capital in the previous year.

The estimate of equation (4) from which household permanent income estimates are obtained is

$$\hat{Y} = Y_p(1) = \underset{(32.77)}{140.59} + \underset{(15.58)}{137.92}LD + \underset{(0.39)}{0.14}LQ + \underset{(4.03)}{16.11}FM - \underset{(36.52)}{68.11}DP - \underset{(38.44)}{143.06}SI,$$

$$R^2 = 0.627, F = 42.07$$

where standard errors are in parentheses. The schooling variable (ED) was dropped; it had a negative coefficient not significantly different from zero. Summary statistics of the permanent (Y_p) and transitory (Y_{tr}) income estimates

[1] Bhalla uses a variance components model on a time-series cross-section data set containing three years of data, arguing that the residuals from a single year cross-section "might" contain differences in permanent income levels. This appears to be more a problem of model specification than of the need for multiple years of data.

[2] Bhalla (p. 47) finds that the choice of weights makes little difference to estimated MPC out of permanent income. The weights used here correspond closely to those derived by Bhalla (p. 48) for an income growth rate of 3.5% and discount rates of 50% to 90%.

from statistical estimation of equation (4) and the weighted averages defined by equation (5) are presented in table 2. The two measures of permanent income have similar standard deviations and a simple correlation of 0.945, indicating that they are providing similar measures of the permanent income status of sample households. In the consumption function estimates, $Y_p(2)$ for each household is adjusted upward by adding mean transitory income (17.9 thousand won) to adjust for trend. This has the effect of increasing estimates of *MPC* out of permanent income because the consumption function is forced through the origin.

Consumption function estimates are presented in tables 3 and 4. The estimates in table 3 are per capita functions while those in table 4 are per household. In table 3, model A shows that the *MPC* out of permanent income is about 0.79, the sum of the coefficients of the two income variables. Because the coefficient of $Y_p(1)$ is statistically significant at the 1% level and the sum of the two coefficients is less than one, the results support the permanent income hypothesis that *MPC* out of permanent income is greater than *MPC* out of transitory income, but less than one. The *MPC* out of transitory income is about 0.21, which is significantly greater than zero at the 1% level. This is consistent with empirical findings in other countries that *MPC* out of transitory income is greater than zero.

The estimated *MPC* out of permanent income from model C is about 0.75, which is very close to that estimated from model A.

Table 2. Summary Statistics of Income Measures, 131 Korean Households, 1970 (1,000 Korean Won)

	Mean	Standard Deviation	Correlation Coefficients $Y_p(2)$	Correlation Coefficients $Y_{tr}(2)$
Disposable income (Y)	236.15	117.40		
Permanent income (Y_p)[a]				
$Y_p(1)$	236.15	92.98	.945	
$Y_p(2)$	218.25	95.11		
Transitory income (Y_{tr})[a]				
$Y_{tr}(1)$	0	71.68		.693
$Y_{tr}(2)$	17.90	41.64	.379	

Note: The official rate of exchange in 1970 was 304 won for one U.S. dollar.
[a] The permanent and transitory income estimates are from equation (4) for $Y_p(1)$ and $Y_{tr}(1)$ and from equation (5) for $Y_p(2)$ and $Y_{tr}(2)$.

Table 3. Per Capita Consumption Function Estimates for 131 Panel Farm Households, 1970 (Standard Errors are in Parentheses)

	With Permanent Income $Y_p(1)$ A	$Y_p(1)$ B	$Y_p(2)$ C	$Y_p(2)$ D
Y	.2117	.2266	.0375	−.0107
	(.0840)	(.0803)	(.0944)	(.0912)
Y_p	.5788	.9629	.7086	1.1087
	(.0872)	(.1456)	(.0915)	(.1341)
(Interaction with Y_p)				
LD		−.2005		−.1747
		(.1632)		(.1435)
SI		−.3439		−.3565
		(.1222)		(.1092)
RT		.0170		.0470
		(.0968)		(.0788)
LQ		−.0007		−.0005
		(.0004)		(.0004)
DP		−.0461		.1261
		(.1078)		(.0911)
Intercept		—		—
MPC at Mean[a]	.79	.83	.75	.81
R^2	.91	.92	.92	.93
S.E.	12.91	12.18	12.36	11.28

Note: Y, Y_p, LD, and LQ are in per capita terms.
[a] *MPC* out of permanent income at the sample mean of the variables.

The *MPC* out of transitory income is essentially zero, supporting Friedman. Overall, it can be concluded from both consumption function estimates that *MPC* out of permanent income is around three-quarters, and is much greater than the *MPC* out of transitory income.

In models B and D of table 3, the additional variables expected to affect consumption behavior are added. In table 4 estimates of the same consumption functions are presented using per household variables instead of per capita variables. The estimated *MPC* out of permanent income at the sample mean of all variables is about 0.83 for $Y_p(1)$ and 0.81 for $Y_p(2)$ in both the per capita and household consumption functions. These estimates are within one standard error of the simple consumption function *MPC* estimates in models A and C.

The results of the additional variables are mixed. Farm size (LD) has the expected negative relationship with *MPC* in all equations, but is not statistically significant in any equation. The income source ratio (SI) has the expected negative coefficients in all equations. It is highly significant in the per capita equa-

Table 4. Household Consumption Function Estimates for 131 Panel Farm Households, 1970 (Standard Errors are in Parentheses)

	With Permanent Income	
	$Y_p(1)$	$Y_p(2)$
Y	.3870	.0084
	(.0725)	(.1264)
Y_p	.5657	.9440
	(.1299)	(.1647)
(Interaction with Y_p)		
LD	−.0406	−.0236
	(.0718)	(.0398)
SI	−.0375	−.1414
	(.1343)	(.1291)
RT	−.0219	−.1087
	(.0785)	(.0716)
LQ	−.00008	−.00009
	(.00007)	(.00007)
DP	−.0266	.1070
	(.1112)	(.1075)
Intercept	—	—
MPC at Mean[a]	.83	.81
R^2	.93	.93
S.E.	59.10	57.65

[a] *MPC* out of permanent income at the sample mean of the variables.

tions of table 3 but not significant in the household equations of table 4. The larger magnitude of the coefficients of *LD* and *SI* in the per capita equations than in the household equations presents a puzzle. There may be an interaction effect among *LD*, *SI*, and family size, but an examination of correlation coefficients and alternative equation estimates did not reveal a solution. In one alternative, where Y and Y_p are per capita, but *LD*, *SI*, and *LQ* are per household, the coefficients of *LD* and *SI* are similar to those in the household functions.

The coefficients of *RT*, *LQ*, and *DP* are not statistically significant. The coefficients of *RT* (rate of return to capital), which did not have the expected sign, are mixed. More detailed information on returns to current investments may have yielded different results. The coefficients of *LQ* (liquid assets) are negative in all equations, while the expected sign was positive. The dependency ratio (*DP*), which had an expected positive relationship with *MPC*, has coefficients of both signs.

Conclusions

Two interesting findings emerge from this study. The first is that farm households in South Korea have saved voluntarily a remarkably large part of their incomes since the early 1960s. During the late 1960s these households saved, on the margin, about one-fifth of their permanent incomes and about four-fifths of their transitory incomes. The second finding is that useful measures of permanent and transitory incomes can be estimated from cross-section data and that these estimates can be helpful in better understanding savings behavior.

The results of our analysis lead us to be optimistic about the possibilities of mobilizing voluntary savings in rural areas of low income countries. Policy makers might be pleasantly surprised by the results of well-designed, rural-savings mobilization programs, especially where rural household incomes are growing substantially. Spurts in income may result in household incomes with significant transitory components which are highly susceptible to saving opportunities and incentives.

[Received July 1978; revision accepted March 1979.]

References

Adams, Dale W. "Mobilizing Household Savings through Rural Financial Markets." *Econ. Develop. and Cultur. Change* 26(1978):547–60.

Adams, Dale W., Truong Q. Canh, and Lien-In Amy Chin. "Changes in Rural Purchasing Power in Taiwan, 1952–72." *Food Res. Inst. Stud.* 14(1975):127–45.

Alamgir, Mohiuddin. "Rural Savings and Investment in Developing Countries: Some Conceptual and Empirical Issues." *Bangladesh Develop. Stud.* 4(1976):1–48.

Bhalla, Surjit S. "Aspects of Savings Behavior in Rural India." Studies in Domestic Finance No. 33. Washington, D.C.: World Bank, 1976.

Brown, Gilbert. *Korean Pricing Policies and Economic Development in the 1960's.* Baltimore, Md.: Johns Hopkins University Press, 1973.

Canh, Troung Quang. "Income Instability and Consumption Behavior: A Study of Taiwanese Farm Households 1964–1970." Ph.D. thesis, Ohio State University, 1974.

Ferber, Robert. "General Theories of Spending or Savings Behavior." *Macroeconomics, Selected Readings,* ed. Edward Shapiro. New York: Harcourt, Brace & Co., 1970.

Friedman, Milton. *A Theory of the Consumption Function.* Princeton, N.J.: Princeton University Press, 1957.

Gordon, Roger H. "Essays on the Causes and Equitable Treatment of Differences in Earnings and Ability."

Ph.D. thesis, Massachusetts Institute of Technology, 1976.

Hyun, Kong-Nam. "Aspects of Rural Household Savings Behavior in Korea, 1962–1974." M.S. thesis, Ohio State University, 1977.

Kelly, A. C., and Jeffery G. Williamson. "Household Savings Behavior in the Developing Economies: The Indonesian Case." *Econ. Develop. and Cultur. Change* 16(1968):385–403.

Lee, Tae Young, Dong Hi Kim, and Dale W. Adams. "Savings Deposits and Credit Activities in South Korean Agricultural Cooperatives 1961–1975." *Asian Survey* 17(1977):1182–94.

Leff, Nathaniel H. "Dependency Rate and Savings Rates." *Amer. Econ. Rev.* 59(1969):886–96.

Lilliard, Lee A. "Inequality: Earnings vs. Human Wealth." *Amer. Econ. Rev.* 67(1977):42–53.

Mikesell, Raymond F., and James E. Zinser. "The Nature of the Savings Function in Developing Countries: A Survey of the Theoretical and Empirical Literature." *J. Econ. Lit.* 11(1973):1–26.

Mizoguchi, Toshiyuki. *Personal Savings and Consumption in Postwar Japan.* Tokyo: Kinokuniya Bookstore Co., 1970.

Ong, Marcia M. L., Dale W. Adams, and I. J. Singh. "Voluntary Rural Savings Capacities in Taiwan, 1960–70." *Amer. J. Agr. Econ.* 58(1976):578–82.

Republic of Korea, Ministry of Agriculture and Fisheries (MAF). *Report on the Results of Farm Household Economy Survey.* Seoul, Korea, various years 1963 through 1977.

Snyder, Donald W. "Econometric Studies of Household Savings Behavior in Developing Countries: A Survey." *J. Develop. Stud.* 10(1974):139–53.

Wai, U Tun. *Financial Intermediaries and National Savings in Developing Countries.* New York: Praeger Publishers, 1972.

Appendix

Definitions of Terms

Consumption (C): all household expenditures not directly related to production activities during the calendar year. It includes an imputed value for in-kind consumption, and also purchases of consumer durables (1,000 won).

Disposable Income (Y): the sum of net farm income and net nonfarm income less tax and interest payments realized by the household during the year. Farm income does not include an adjustment for capital depreciation, but does include an estimated value of in-kind household consumption and inventory changes in products (1,000 won).

Farm Size (LD): the total hectares of cultivated land included in the farm enterprise. Most of this land is owner-operated.

Source of Income Ratio (SI): the ratio of gross farm income to total gross household income.

Rate of Return to Capital (RT): the ratio of gross household income to total assets of the previous year. Ratios for the previous year are used because investment decisions are likely heavily influenced by recent returns to investment.

Liquid Asset Holdings (LQ): the values of product inventories, small animals, and cash and quasi-cash holdings such as deposits and money lent at the beginning of the year (1,000 won).

Dependency Ratio (DP): the ratio of family members less than fifteen or over sixty years of age to total family members.

Family Size (FM): the total number of individuals who resided in the household during most of the calendar year.

Education (ED): the average years of schooling of household members more than six years of age.

Farm-Level Fertilizer Demand for Mexican Wheat Varieties in the Indian Punjab

Surjit S. Sidhu and Carlos A. Baanante

A restricted profit function is used to estimate jointly the profit and factor demand functions from farm-level, cross-sectional data for Mexican wheat varieties in the Indian Punjab. The main focus is analysis of fertilizer demand. The results indicate that output price is a more powerful policy instrument than fertilizer price to influence fertilizer use, output supply, and returns to fixed farm resources, that producers attain allocative efficiency, that education of the farm people contributes significantly to agricultural production, and that profit function is a suitable concept for empirical analysis and interpretation.

Key words: fertilizer demand, Indian Punjab, Mexican wheat varieties, policy, restricted profit function.

The role of fertilizer in agricultural development has been widely recognized and is well documented by Sahota (1968, 1977), Hayami-Ruttan, Pinstrup-Andersen, and others. However, as noted by Timmer, only a limited amount of systematic or generalizable knowledge exists about the sources of expansion in fertilizer use at the farm level. This has resulted partly because of inherent difficulties in specifying farm-level input demand functions and gathering appropriate data for their estimation and partly because of the inadequacies of the methodological procedures employed to study farm-level fertilizer demand. As a consequence there has been insufficient knowledge of the policy options available and the ways to manipulate them for accelerating the rate of expansion of fertilizer use. As the role of fertilizer in agricultural development of the developing countries increases, this insufficiency is being felt more acutely. The importance of a better understanding of the sources which make possible an accelerated expansion and more efficient usage of fertilizer is further underscored by a substantial worldwide increase in planned fertilizer capacity consequent to the early and mid-1970s increase of fertilizer prices.

Lau and Yotopoulos (L-Y) in their (1972) paper and Sidhu (1974b) have applied the profit function concept to study farm-level factor demand and output supply functions. More recently Yotopoulos, Lau, and Lin (Y-L-L) have extended this work to study farm households in Taiwan and included four variable inputs instead of one. The results of these studies suggest that in the study of farm-level problems, the application of the normalized restricted profit function and factor demand functions is a more reasonable and less problematic approach. Such an approach overcomes many of the problems associated with direct estimation of production and demand functions.

In an earlier paper, using a single equation, production function approach and 1967–68 farm-level data, Sidhu (1974a) compared old and Mexican wheat varieties and reported that in the Indian Punjab demand functions per unit of land for chemical fertilizer and other inputs increased by 25% resulting from the introduction of Mexican varieties of wheat. The purpose of this paper is to estimate farm-level demand for fertilizer, labor, and irrigation water based on the profit function formulation applied to 1970–71 cross-sectional data from farms producing Mexican wheat varieties in the Indian Punjab and to derive implications helpful to design appropriate policies to promote efficient use of fertilizer. Here it should

---

Surjit S. Sidhu and Carlos A. Baanante are economists at the International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama.

Financial support from the Rockefeller Foundation and the Economic Development Center, University of Minnesota, is acknowledged.

The authors would like to acknowledge the helpful comments from colleagues at IFDC and Vernon W. Ruttan and Lawrence J. Lau.

be emphasized that the main thrust of the paper is analysis of farm-level fertilizer demand and that the demand equations for labor and irrigation water are included to specify more fully the model and to study their interrelatedness to fertilizer demand. The paper supplements L-Y and Y-L-L conclusions in favor of the profit function formulation as an important tool for empirical analysis of production using farm-level data. The present model, as compared to Sidhu's (1974b) study, is much better specified. Inclusion of chemical fertilizer and irrigation water, in addition to labor, as variable inputs and inclusion of education as a fixed input of production, are major improvements of the wheat production function. Results from treating education of the farm family members as a fixed input provide support for the hypothesis that education contributes to technical efficiency in production. Also the earlier finding of Sidhu (1974b) of equal economic performance of small and large wheat farms is confirmed by this extended model.

In the following four sections, a brief description of the profit-function formulation and estimating procedure is provided, the data and statistical assumptions are described, empirical results are discussed, and implications for fertilizer policy are derived. The summary and conclusions are presented in the final section.

The Profit Function Model

The wheat production function for the Indian Punjab farms with the usual neoclassical properties is specified as:

$$(1) \qquad Y = f(N, F, I; L, K, E),$$

where Y is output, N, F, and I are the variable inputs of labor, chemical fertilizer, and irrigation water, and L, K, and E are the fixed inputs of land, capital, and education, respectively.

There is a one-to-one correspondence between production function (1) and the related normalized, restricted-profit function (Lau, Diewert, L-Y and Y-L-L). Per farm restricted profit π is defined as total current revenue from wheat less total current variable costs and after normalization by the price of wheat p is expressed as a function of the normalized prices of the variable inputs N, F, and I and the quantities of fixed inputs L, K, and E, as follows:

$$(2) \quad \pi^* = \frac{\pi}{p} = g(p_i; L, K, E), \quad i = N, F, I.$$

Given this normalized profit function, the original production function (*a*) can be recovered by the conjugacy operation (Diewert, Lau). Following Y-L and Y-L-L, demand functions for the variable factors of production are obtained by differentiating the normalized profit function (*b*) with respect to the respective normalized factor prices:

$$(3) \qquad X_i = -\frac{\partial \pi^*}{\partial p_i}; \; i = N, F, I,$$

with X_i the quantity of factor i. For empirical analysis of short-run production situations, it is more appropriate to work with the concept of normalized restricted profit function than the production function, first, because it is a function only of predetermined variables and thus econometrically more appropriate for estimation, and second, because the system of factor demand functions and output supply function obtained from the normalized restricted profit function facilitates interpretation and analysis for deriving policy implications. In view of the detailed methodological developments of the normalized restricted profit function formulation by Lau, Diewert, and L-Y, it is not necessary to reproduce a full detail of the model and the related derivations.

We proceed further by assuming that the wheat production function (1) is Cobb-Douglas in form. The estimating equations (2) and (3) can be specified as follows:

$$(4) \quad \ln \pi^* = \ln A^*_S + \delta_L D_L + \alpha^*_N \ln p_N + \alpha^*_F \ln p_F + \alpha^*_I \ln p_I + \beta^*_L \ln L + \beta^*_K \ln K + \beta^*_E \ln E,$$

$$(5) \qquad -\frac{p_N \cdot N}{\pi^*} = \alpha^*_{NL} D_L + \alpha^*_{NS} D_S,$$

$$(6) \qquad -\frac{p_F \cdot F}{\pi^*} = \alpha^*_{FL} D_L + \alpha^*_{FS} D_S,$$

$$(7) \qquad -\frac{p_I \cdot I}{\pi^*} = \alpha^*_{IL} D_L + \alpha^*_{IS} D_S,$$

where (4) is the normalized restricted profit function in the logarithmic form and (5), (6), and (7) are the factor share equations for labor, chemical fertilizer, and irrigation water, respectively. This is a system in which the restricted profit and factor shares are a set of jointly determined variables.

The parameters in equations (5), (6), and (7) are equal to the corresponding parameters in equation (4) only if farms maximize profits. The hypothesis of profit maximizing, therefore, can be tested explicitly for price-taking farms (L-Y, Y-L-L). It should be pointed out that α^*_i ($i = N, F, I$) and β^*_j ($j = L, K, E$) are related to the coefficients of the Cobb-Douglas production function (1) by (Y-L):

$$(8) \quad \alpha^*_i = -\alpha_i(1-u)^{-1} < 0 \qquad i = N, F, I,$$

and

$$(9) \quad \beta^*_j = \beta_i(1-u)^{-1} > 0 \qquad j = L, K, E.$$

where u is equal to $\Sigma_i\alpha_i < 1$; and α_i are the production elasticities of the variable inputs.

Equations (4), (5), (6), and (7) form Model I, which is used to compare economic efficiency and its components of technical efficiency and price efficiency of small (less than 10 acres) and large (greater than 10 acres) wheat farms. The dividing line is maintained at 10 acres to facilitate comparisons of our results with numerous earlier studies which also have used this criterion for small and large farms. If small and large farms have the same efficiency parameters, the dummy variables D_L and D_S are excluded from Model I, and this is called Model II.

The Data and Statistical Assumption

The basic farm-level data for this research pertain to the crop year 1970–71 and were obtained from a stratified random sample spread over four different parts of the state and are thus quite representative of wheat production in the Indian Punjab. The design and data collection work were carried out under the supervision of one of the authors. The data have earlier been used in Sidhu (1974a, 1974b, and 1976). Only Mexican varieties of wheat were grown on the farms studied.

A brief description of the variables and the notation used is as follows:

Y, physical output of wheat measured in kilograms per farm including by-products (converted into kilograms of wheat by dividing the total value of by-products by wheat price);

N, labor input per farm used for wheat production measured in hours including both family and hired labor (child and female labor is converted into man equivalents by treating two children, or women, equal to one man);

F, fertilizer input per farm, measured as kilograms of plant nutrients of nitrogen, P_2O_5, and K_2O;

I, irrigation water measured as the number of acre-irrigations per farm (an acre-irrigation simply represents the amount of water required to irrigate once an acre of land by flood irrigation method);

L, land input measured as acres of wheat grown per farm;

K, an annualized flow measure of capital services including animal capital going into wheat production per farm;

E, the average number of years of schooling per family member (over thirteen years of age) of the farm household;

π^*, the restricted profit from wheat production per farm: total revenue less total costs of labor, chemical fertilizer, and irrigation water normalized by the price of wheat;

p_N, p_F, p_I, the money wage rate per hour, the money price of fertilizer nutrients per kilogram, and the money price of irrigation water per acre of irrigation, respectively, all normalized by the price of wheat;

D_L, dummy variable taking the value of one if wheat area is larger than 10 acres, and zero otherwise; and

D_S, dummy variable taking the value of one if wheat area is less than or equal to 10 acres, and zero otherwise.

For statistical specification, following earlier L-Y, Y-L-L, and Sidhu (1974b) studies, additive errors with zero expectation and finite variance are assumed for each of the four equations of the model. The covariances of the errors of any two of the equations for the same farm may not be zero but the covariances of the errors of any two equations corresponding to different farms are assumed to be identically zero. Under these assumptions an asymptotically efficient method of estimation as proposed by Zellner is used to estimate equations (4), (5), (6), and (7) simultaneously.

Empirical Results

In an earlier paper Sidhu (1974b) reported that small and large wheat-producing farms in the Indian Punjab have equal relative economic efficiency, equal relative price efficiency, and also equal technical efficiency. However, the model was specified to include only labor as a variable input. The present model includes labor, chemical fertilizer, and irrigation water

as variable inputs. The extended model (Model I) is first used to compare the economic efficiency and its components of price efficiency and technical efficiency of small and large farms. The test statistics (*i*) and (*ii*) presented in table 1 show that the hypotheses that small and large farms have equal relative economic efficiency and equal relative price efficiency parameters with respect to labor, fertilizer, and irrigation water cannot be rejected at 1% level of significance. This implies that these farms also have equal technical efficiency parameters.

Next, maintaining the hypothesis of equal price efficiency between small and large farms, the hypothesis of absolute price efficiency (profit-maximizing) for both small (*iii*) and large (*iv*) farms is tested. The test statistics are presented in table 1. Again, the hypothesis is not rejected at the 1% level of significance, both for small and large farms. These results confirm the previous findings (Sidhu 1974b) and indicate that the degree of economic motivation and success in the allocation of their resources in the Indian Punjab is not significantly different among small and large wheat producers, that they are able to allocate their resources successfully in the profit-maximizing sense, and also that their technical efficiency is not significantly different. Based on these results, only Model II, which does not include the dummy variables D_L and D_S, is employed for all subsequent analyses.

The hypothesis of profit maximization with respect to variable inputs of labor, fertilizer, and irrigation was tested again (v, table 2) from Model II and is not rejected at 1% level. Maintaining this hypothesis, the hypothesis of constant returns to scale in all inputs except education (vi, table 2) is tested: *Ho:* $\beta^*_L + \beta^*_K = 1$. This hypothesis also is not rejected.

The results of the single-equation, ordinary least squares estimation and the joint estimation (using Zellner's method) of the Cobb-Douglas profit function and three factor demand equations for labor, chemical fertilizer, and irrigation water (Model II) are presented in table 3. Because the hypotheses of profit maximization and constant returns to scale have not been rejected, these linear constraints are also imposed. Estimates with both restrictions presented in the last column of table 3 are used for the purpose of further discussion and analyses.

In table 4, derived estimates of the input elasticities of production for the Cobb-Douglas production function underlying the normalized restricted profit function are presented. These estimates are derived from identities (8) and (9). In view of the improved specification, these estimates of the wheat production function are superior to those reported by Sidhu (1974b). Econometrically, the estimates are consistent and asymptotically efficient. It should be noted that the estimates with and without imposing the constraint of constant returns to scale are almost identical. In terms of relative contribution of different factors to wheat production, land is by far the most important factor, followed by labor. Fertilizer contributes to wheat output by over 9% and corresponds very closely to the Evenson estimate (0.0796) in cereal grain production and the Y-L-L estimate (0.1026) for Taiwan agricul-

Table 1. Statistical Hypotheses Tested, Model I

Maintained Hypotheses	Tested Hypotheses, *Ho*	Computed *F*	Critical *F* Values *F*0.05	Critical *F* Values *F*0.01
	(*i*) $S_L = 0$	$F(1, 370) = 1.021$	3.841	6.634
	(*ii*) $\alpha^*_{NS} = \alpha^*_{NL}$ $\alpha^*_{FS} = \alpha^*_{FL}$ $\alpha^*_{IS} = \alpha^*_{IL}$	$F(3, 370) = 2.854$	2.605	3.781
$\alpha^*_{NS} = \alpha^*_{NL}$ $\alpha^*_{FS} = \alpha_{FL}$ $\alpha_{IS} = \alpha_{IL}$	(*iii*) $\alpha^*_{NS} = \alpha^*_N$ $\alpha^*_{FS} = \alpha^*_F$ $\alpha^*_{IS} = \alpha^*_I$	$F(3, 373) = 3.080$	2.605	3.781
$\alpha^*_{NS} = \alpha^*_{NL}$ $\alpha^*_{FS} = \alpha^*_{FL}$ $\alpha^*_{IS} = \alpha^*_{IL}$	(*iv*) $\alpha^*_{NL} = \alpha^*_N$ $\alpha^*_{FL} = \alpha^*_F$ $\alpha^*_{IL} = \alpha^*_I$	$F(3, 373) = 3.080$	2.605	3.781

[a] Second subscripts *S* and *L* stand for small and large farms and the coefficients without second subscript belong to the profit equation (2).

Table 2. Statistical Hypotheses Tested: Model II

Maintained Hypotheses[a]	Tested Hypotheses,[a] *Ho*	Computed *F*	Critical *F* Values *F*0.05	Critical *F* Values *F*0.01
	(*v*) $\alpha^*_{ND} = \alpha^*_N$ $\alpha^*_{FD} = \alpha^*_F$ $\alpha^*_{ID} = \alpha^*_I$	$F(3, 374) = 2.775$	2.605	3.781
$\alpha^*_{ND} = \alpha^*_N$ $\alpha^*_{FD} = \alpha^*_F$ $\alpha^*_{ID} = \alpha^*_I$	(*vi*) $\beta^*_L + \beta^*_K = 1$	$F(1, 377) = 0.792$	3.841	6.634

[a] Coefficients with *D* as second subscript belong to the factor share equations and the ones with no second subscript to the profit equation (2).

ture. It is worth noting here that education of the farm household makes a small but positive (1.7%) contribution to wheat production by improvement in technical efficiency or what Welch has called the "worker effect."[1]

[1] Wu also has reported significant contribution of education as "worker effect" in Taiwan farm production. See also Sidhu (1976) for similar results in case of the Indian Punjab. Huffman, on the other hand, reports in the case of United States agriculture that the contribution of education is only an "allocative effect."

Implications for Fertilizer Policy

In order to increase wheat production two types of policies are of relevance: (*a*) those directed towards generating technical shifts in the production function, for example, production of new biological materials and information and (*b*) the pricing and other policies for influencing the use of fertilizer and other inputs of production. The first type of policy resulted in approximately a 25% shift

Table 3. Results of Joint Estimation of Cobb-Douglas Profit Function and Labor, Fertilizer, and Irrigation Demand Functions for Mexican Wheat 1970–71, Punjab, India

Profit Function	Parameter	Single Equation Ordinary Least Squares	Seemingly Unrelated Regression Estimates: Unrestricted	Restriction 1[a]	Restriction 2[b]
Constant	$\ln A^*$	5.459	5.425	5.448	5.650
		(1.058)[c]	(0.714)	(0.453)	(0.396)
Labor	α^*_N	−0.717	−0.096	−0.441	−0.441
		(0.288)	(0.194)	(0.028)	(0.028)
Fertilizer	α^*_F	−0.874	−0.424	−0.161	−0.161
		(0.781)	(0.527)	(0.008)	(0.008)
Irrigation	α^*_I	−0.029	−0.021	−0.108	−0.108
		(0.076)	(0.051)	(0.009)	(0.009)
Land	β^*_L	0.406	0.294	0.279	0.256
		(0.123)	(0.083)	(0.082)	(0.077)
Capital	β^*_K	0.605	0.727	0.755	0.744
		(0.124)	(0.084)	(0.078)	(0.077)
Education	β^*_E	0.023	0.033	0.026	0.030
		(0.035)	(0.024)	(0.023)	(0.023)
Demand Functions					
Labor	α^*_{ND}	−0.460	−0.460	−0.441	−0.441
		(0.029)	(0.029)	(0.028)	(0.028)
Fertilizer	α^*_{FD}	−0.164	−0.164	−0.161	−0.161
		(0.009)	(0.009)	(0.008)	(0.008)
Irrigation	α^*_{ID}	−0.114	−0.114	−0.108	−0.108
		(0.010)	(0.010)	(0.009)	(0.009)

[a] $\alpha^*_{ND} = \alpha^*_N$; $\alpha^*_{FD} = \alpha^*_F$; $\alpha^*_{ID} = \alpha^*_I$.
[b] $\alpha^*_{ND} = \alpha^*_N$; $\alpha^*_{FD} = \alpha^*_F$; $\alpha^*_{ID} = \alpha^*_I$; $\beta_L + \beta_K = 1$.
[c] Asymptotic standard errors are in parentheses.

Table 4. Derived Estimates of Input Elasticities of the Cobb-Douglas Production Function

Inputs	Parameters	Estimates: Restriction 1	Restriction 2
Labor	α_N	0.258	0.258
Fertilizer	α_F	0.094	0.094
Irrigation	α_I	0.063	0.063
Capital	β_L	0.163	0.150
Land	β_K	0.441	0.435
Education	β_E	0.015	0.017
$\alpha_N + \alpha_F = \alpha_I + \beta_L + \beta_K$		1.019	1.000

in the per acre fertilizer and other input demand functions (Sidhu 1974a). But, in a market economy like that of the Indian Punjab, it is also quite important to understand the role that the second type of policy can play, and this is the focus of the following discussion.

A number of important elasticity estimates derived from the estimates presented in table 3 are presented in table 5. All of these elasticities have the expected signs, indicating that the results are in accord with the usual hypotheses. There are several important implications that follow from these numerical estimates.

The elasticities of output supply function and fertilizer and other variable input demand functions indicate quite an elastic response to changes in wheat price. In fact, the price of wheat is the most important variable influencing factor use in wheat production. Similarly, all own-price elasticities of variable input demand functions indicate an elastic response of factor utilization. The cross-price elasticities of the variable input demand functions are all smaller in absolute value (by exactly one) than the own-price elasticities and are all negative, indicating that the variable inputs are complements. But it should be pointed out that these facts are both consequences of the assumption of Cobb-Douglas production function. However, a comparison of the absolute magnitudes of the cross elasticities presented in table 5, indicates that labor and fertilizer are stronger complements than fertilizer and irrigation. Y-L-L have obtained similar results in the case of Taiwan. Further work using more appropriate functional forms; for example, cost function approach, is necessary to sort out empirically which factors are economic complements or substitutes. Such work obviously has important policy implications.

These elasticity estimates provide important information for determining the influence and repercussions of specified changes in output price, a single variable input price, or different combinations of them. Implications of some such selected policies for factor use, output supply, and returns to fixed factors are presented in table 6.

The output supply and input demand elasticities with respect to the fixed factors of production of land, capital assets, and education indicate the response to exogenous changes in these factors, holding the prices of output and variable inputs constant, but allowing output and variable inputs to adjust optimally. For this reason the response indicated by these reduced-form elasticities is much larger than the corresponding production function elasticities. These elasticities are also more meaningful and relevant measures of the effects of policy changes. Elasticities with respect to land and physical capital assets indicate, as expected, a substantial response to exogenous increases in their quantities.

The role and significance of productive value of education should again be pointed out. The indicated shift in output supply and factor demand functions, resulting from a small amount of education of about 2.6 years of schooling per family member, is 3%. This *mutatis mutandis* effect of education is larger

Table 5. Own- and Cross-Price Elasticities of Variable Inputs and Elasticities with Respect to Fixed Inputs and Education

		Price of Wheat (p)	Price of Labor (p_N)	Price Fert. (p_F)	Price Irrigation (p_I)	Land L	Capital K	Education E
Wheat supply	W	0.710	−0.441	−0.161	−0.108	0.744	0.256	0.030
Labor	N	1.710	−1.441	−0.161	−0.108	0.744	0.256	0.030
Fertilizer	F	1.710	−0.441	−1.161	−0.108	0.744	0.256	0.030
Irrigation	I	1.710	−0.441	−0.161	−1.108	0.744	0.256	0.030

Table 6. Implications of Selected Policies

Policy	Percentage Effect on						
	Use of Labor	Use of Fertilizer	Use of Irrigation	Wheat Output	Returns to Land	Returns to Capital	Returns to Education
1. 10% decrease in price of fertilizer	1.61	11.61	1.61	1.61	1.61	1.61	1.61
2. 10% decrease in price of irrigation water	1.08	1.08	11.08	1.08	1.08	1.08	1.08
3. (1) + (2)	2.69	12.69	12.69	2.69	2.69	2.69	2.69
4. 10% increase in price of wheat	17.10	17.10	17.10	7.10	17.10	17.10	17.10

Note: Effects of different policies on use of labor, fertilizer, and irrigation water, and on output supply and returns to fixed factors of land, physical capital assets, and education are obtained from the output supply and factor demand elasticities presented in table 5.

than the "worker effect" because output and variable inputs have been allowed to adjust optimally holding their prices and other fixed factors constant. This, however, is not a total measure of the productive value of education in agricultural production since wheat is only one of the several farm enterprises on Punjab farms.

Summary and Conclusions

There are four substantial conclusions that follow from the analysis of our data. First, the findings (from the three variable input-extended models) that there are no differences in the technical and price efficiency parameters of small and large farms, that both classes of farms maximize profits, and that there exist constant returns to scale in wheat production in the Indian Punjab suggest that opportunities for growth by improving farmers' allocative efficiency are almost nonexistent and that policy considerations of farm size may be based only on social and political considerations. Second, the impact on fertilizer use and wheat output of a 1% decrease in fertilizer price is not symmetric with a 1% increase in wheat price. Wheat price appears to be a much more powerful policy instrument than fertilizer price to influence fertilizer use, output supply, and returns to fixed-farm resources. These results lend support to Krishna's argument in favor of output price support versus input subsidization for accelerating growth of agricultural output in the developing economies[2] and have important consequences for fertilizer- (and other input) pricing policies (Hsu) and for short-term fertilizer (and other inputs) demand projections (Timmer, p. 203). Third, the results support the conclusion that education of farm people in Punjab contributes significantly to agricultural production. Finally, the results provide strong support for the approach using normalized profit function and factor demand functions in empirical applications of economic theory for deriving useful policy implications from farm-level data.

[*Received July 1978; revision accepted November 1978.*]

[2] In the case of the Philippines, Barker and Hayami argue in favor of fertilizer subsidy rather than output price support. They, however, assume zero cross-price elasticities in input demand functions and much smaller values for output supply elasticity and own-price elasticity (absolute value) of fertilizer demand than the estimates presented in this paper.

References

Barker, Randolph, and Yujiro Hayami. "Price Support versus Input Subsidy for Food Self-Sufficiency in Developing Countries." *Amer. J. Agr. Econ.* 58(1976):617–28.

Diewert, W. E. "Functional Forms for Profit and Transformation Functions." *J. Econ. Theory* 6(1973): 284–316.

Evenson, Robert. "The 'Green Revolution' in Recent Development Experience." *Amer. J. Agr. Econ.* 56(1974):387–94.

Hayami, Yujiro, and Vernon W. Ruttan. *Agricultural Development: An International Perspective.* Baltimore, Md.: Johns Hopkins University Press, 1971.

Hsu, Robert C. "First-Best and Second-Best Policies of Pricing an Imported Input: The Case of Fertilizer in Taiwan, 1950–1966." *Amer. J. Agr. Econ.* 56(1974):314–22.

Huffman, Wallace E. "Decision Making: The Role of Education." *Amer. J. Agr. Econ.* 56(1974):85–97.

Krishna, Raj. "Agricultural Price Policy and Economic

Development." *Agricultural Development and Economic Growth,* ed. H. M. Southworth and B. F. Johnston, pp. 497–540. Ithaca, N.Y.: Cornell University Press, 1967.

Lau, L. J. "A Characterization of the Normalized Restricted Profit Function." *J. Econ. Theory* 12(1976):131–63.

Lau, L. J., and P. A. Yotopoulos. "Profit, Supply, and Factor Demand Functions." *Amer. J. Agr. Econ.* 54(1972):11–18.

Pinstrup-Andersen, Per. "Preliminary Estimates of the Contribution of Fertilizer to Cereal Production in Developing Market Economies." *J. Econ.* 11(1976):169–72.

Sahota, Gian S. *Fertilizer in Economic Development: An Econometric Analysis*. New York: Praeger Publishers, 1968.

———. *The Role of Fertilizer in the New International Economic Order*. Unpublished paper, Nov. 1977.

Sidhu, Surjit S. "Economics of Technical Change in Wheat Production in the Indian Punjab." *Amer. J. Agr. Econ.* 56(1974a):217–26.

———. "The Productive Value of Education in Agricultural Development." Dep. Agr. and Applied Econ. staff pap. P76-17, University of Minnesota, 1976.

———. "Relative Efficiency in Wheat Production in the Indian Punjab." *Amer. Econ. Rev.* 64(1974b):742–51.

Timmer, C. Peter. "The Demand for Fertilizer in Developing Countries." *Food Res. Inst. Stud.* (1974):197–224.

Welch, Finis. "Education in Production." *J. Polit. Econ.* 78(1970):35–59.

Wu, Craig C. "Education in Farm Production." *Amer. J. Agr. Econ.* 59(1977):699–709.

Yotopoulos, P. A., and L. J. Lau. "A Test for Relative Economic Efficiency: Some Further Results." *Amer. Econ. Rev.* 63(1973):214–223.

Yotopoulos, P. A., L. J. Lau, and W. L. Lin. "Microeconomic Output Supply and Factor Demand Functions in the Agriculture of the Province of Taiwan." *Amer. J. Agr. Econ.* 58(1976):333–40.

Zellner, A. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *J. Amer. Statist. Assoc.* 57(1962):348–75.

Determinants of Supply Elasticity in Interdependent Markets

Bruce L. Gardner

This paper draws out the implications of equilibrium in a two-product, two-factor model for elasticity of product supply, which is found to depend upon input supply elasticities, alternative product demand elasticity, elasticity of substitution between production inputs, relative factor intensity of the product, and relative importance of the product in its use of resources. These factors interact in a complex manner to determine supply elasticity. The author discusses related approaches of Buse, Muth, and Powell and Gruen, and considers several simplified examples in an attempt to provide an intuitive grasp of the workings of the model.

Key words: commodity interaction, supply.

When a farm product price is expected to change (because of a prospective farm program change, for example), an important job for economic analysis is to explain the process by which commodity production responds and to predict the results. This job is made complicated by interaction among related commodity markets. Buse, and Powell and Gruen have made important contributions on how to proceed empirically in such circumstances, but there has not been an analysis of the underlying determinants of supply elasticity in the multiproduct case to correspond to the work of Muth for a single product. This paper derives own- and cross-price elasticities of supply from underlying input supply, competing product demand, and production functions. This task is undertaken chiefly in a two-product, two-input case which brings out the main (though not all the important) features of market interaction, while still permitting an intuitive grasp of the reasoning. The paper develops formulas for own-price and cross-price elasticities as functions of underlying behavioral parameters, shows their relationship to existing single product results in the literature, and discusses potential applications in analyzing response to demand shifts, effects of farm program price changes, and input supply shifts.

Bruce Gardner is a professor in the Department of Agricultural Economics, Texas A&M University.

This is Journal Article No. TA14652 of the Texas Agricultural Experiment Station.

The Two-Product, Two-Input Model

The basic behavioral equations of the model are as follows.[1] First, two-product demand functions:

$$(1) \qquad x = x^D(P_x, P_y),$$

$$(2) \qquad y = y^D(P_x, P_y),$$

where x and y are quantities of two products and P_x and P_y are their prices. The demand functions may also contain exogenous variables such as income, population, other prices, but these are held constant for present purposes and are therefore omitted.

Second, there are two production functions:

$$(3) \qquad x = f(a_x, b_x),$$

$$(4) \qquad y = g(a_y, b_y),$$

where a_x and a_y are the quantity of input a used in x and y production, and b_x and b_y mean the same for input b. The production functions allow any degree of substitutability between the inputs but are assumed to have the constant elasticity of substitution (CES) form with constant returns to scale. While the mar-

[1] This model differs from the standard macroeconomic two-sector models (e.g., Johnson) in that the two products here do not exhaust the economy, so that factors may have other uses besides the products specified; incomes of consumers are not determined by factor receipts; and there are as many relative prices as there are products plus factors, i.e., no numeraire is necessary. However, results from the production side of both models (such as the derivation of the production possibilities curve) are basically analogous.

kets are interdependent, the two products are not produced in the same production process, i.e., production is "nonjoint" as the term is used by Hall (p. 880).

Third, there are two input supply functions,

$$P_a = S^a(a_x + a_y), \text{ and} \tag{5}$$

$$P_a = S^b(b_x + b_y), \tag{6}$$

which, like the product demand functions, are unconstrained as to form but assumed to have the usual slopes.

Finally, there are four equilibrium conditions for the industry's factor use:

$$P_a = \frac{\partial x}{\partial a_x} P_x, \tag{7}$$

$$P_b = \frac{\partial x}{\partial b_x} P_x, \tag{8}$$

$$P_a = \frac{\partial y}{\partial a_y} P_y, \text{ and} \tag{9}$$

$$P_b = \frac{\partial y}{\partial b_y} P_y. \tag{10}$$

Equations (1) to (10) constitute a system of ten equations in ten unknowns (x, P_x, y, P_y, a_x, a_y, P_a, b_x, b_y, P_b). To find the supply elasticity in this system, equation (1) is dropped and the remaining equations are differentiated with respect to P_x. After converting to elasticities, the differentiated system is from production functions:

$$E_x = k_{ax}E_{a_xP_x} + k_{bx}E_{b_xP_x}, \tag{11}$$

$$E_{yP_x} = k_{ay}E_{a_yP_x} + k_{by}E_{b_yP_x}, \tag{12}$$

from equilibrium conditions:

$$E_{P_aP_x} = -\frac{k_{bx}}{\sigma_x} E_{a_xP_x} + \frac{k_{bx}}{\sigma_x} E_{b_xP_x} + 1, \tag{13}$$

$$E_{P_bP_x} = \frac{k_{ax}}{\sigma_x} E_{a_xP_x} - \frac{k_{ax}}{\sigma_x} E_{b_xP_x} + 1, \tag{14}$$

$$E_{P_aP_x} = -\frac{k_{by}}{\sigma_y} E_{a_yP_x} + \frac{k_{by}}{\sigma_y} E_{b_yP_x} + E_{P_yP_x}, \tag{15}$$

$$E_{P_bP_x} = \frac{k_{ay}}{\sigma_y} E_{a_yP_x} - \frac{k_{by}}{\sigma_y} E_{b_yP_x} + E_{P_yP_x}, \tag{16}$$

from factor-supply equations:

$$E_{P_aP_x} = \frac{1}{e_a} (\alpha_x E_{a_xP_x} + \alpha_y E_{a_yP_x}), \tag{17}$$

$$E_{P_bP_x} = \frac{1}{e_b} (\beta_x E_{b_xP_x} + \beta_y E_{b_yP_x}), \tag{18}$$

and from demand equation:

$$E_{yP_x} = \eta_y E_{P_yP_x} + \eta_{yP_x}. \tag{19}$$

A glossary of terms used in equations (11) to (19) and throughout the paper is provided in table 1. E_{yP_x} stands for "percentage change in y divided by percentage change in P_x," i.e., the elasticity of y with respect to P_x. The meaning of the other E . . variables is analogous. The E's are total elasticities in that they do not show the response of y to P_x holding P_y, P_a, etc., constant; instead, all the endogenous variables are allowed to adjust to new equilibrium values simultaneously.

By equating (12) and (19), (13) and (17), (14) and (18), (15) and (17), and (16) and (18), the system of equations (11) to (19) can be reduced to the following five-equation system in the five unknowns $E_{a_xP_x}$, $E_{a_yP_x}$, $E_{b_xP_x}$, $E_{b_yP_x}$, and $E_{P_yP_x}$:

Table 1. Identification of Symbols Used

$E_{i,j}$	Total elasticity of variable i with respect to a change in variable j.
e_a, e_b	Own-price elasticities of supply of inputs a and b.
σ_x	Elasticity of substitution between a and b in x production.
η_{yP_x}	Elasticity of demand for y with respect to a change in the price of x.
η_y	Own-price elasticity of demand for y.
a_x, a_y, b_x, b_y	Quantity of inputs a and b used in production of x and y.
$\alpha_x, \alpha_y, \beta_x, \beta_y$	Fraction of total factor a and b use accounted for by commodities x and y, e.g., $\alpha_x = a_x/(a_x + a_y)$.
$k_{ax}, k_{ay}, k_{bx}, k_{by}$	Fraction of total cost of x (or y) accounted for by a (or b). ($k_{ax} + k_{bx} = 1$ and $k_{ay} + k_{by} = 1$.)
ϕ	Factor-intensity coefficient, $k_{ax}k_{by} - k_{ay}k_{bx} (= k_{ax} - k_{ay})$.

(20)

$$\begin{bmatrix} -\eta_y & 0 & k_{ay} & 0 & k_{by} \\ 0 & \left(\dfrac{\alpha_x}{e_a} + \dfrac{k_{bx}}{\sigma_x}\right) & \dfrac{\alpha_y}{e_a} & -\dfrac{k_{bx}}{\sigma_x} & 0 \\ -1 & \dfrac{\alpha_x}{e_a} & \left(\dfrac{\alpha_y}{e_a} + \dfrac{k_{by}}{\sigma_y}\right) & 0 & -\dfrac{k_{by}}{\sigma_y} \\ 0 & -\dfrac{k_{ax}}{\sigma_x} & 0 & \left(\dfrac{\beta_x}{e_b} + \dfrac{k_{ax}}{\sigma_x}\right) & \dfrac{\beta_y}{e_b} \\ -1 & 0 & -\dfrac{k_{ay}}{\sigma_y} & \dfrac{\beta_x}{e_b} & \left(\dfrac{\beta_y}{e_b} + \dfrac{k_{ay}}{\sigma_y}\right) \end{bmatrix} \begin{bmatrix} E_{P_yP_x} \\ E_{a_xP_x} \\ E_{a_yP_x} \\ E_{b_xP_x} \\ E_{b_yP_x} \end{bmatrix} = \begin{bmatrix} -\eta_{yP_x} \\ 1 \\ 0 \\ 1 \\ 0 \end{bmatrix}$$

Total Elasticity of Supply

After solving this system for $E_{a_xP_x}$ and $E_{b_xP_x}$, the solutions are inserted in equation (11) to obtain

$$\begin{aligned} (21)\quad E_x = {} & [e_ae_b + k_{ax}e_a\sigma' + k_{bx}e_b\sigma'' \\ & - \phi\sigma_y(\beta_ye_a + \alpha_ye_b) - \eta_y(\beta_yk_{by}e_a \\ & + \alpha_yk_{ay}e_b + \alpha_yk_{ax}\sigma' + \beta_yk_{bx}\sigma'') \\ & - \eta_{yP_x}(\beta_yk_{bx}e_a + \alpha_yk_{ax}e_b \\ & + \alpha_yk_{ax}\sigma' + \beta_yk_{bx}\sigma'')]/\alpha_x\sigma' \\ & + \beta_xk_{bx}e_a + \alpha_xk_{ax}e_b \\ & + k_{bx}\sigma_y(\beta_x - \alpha_x) + \eta_y\phi(\beta_x - \alpha_x), \end{aligned}$$

where $\sigma' = \beta_x\sigma_x + \beta_y\sigma_y$ and $\sigma'' = \alpha_x\sigma_x + \alpha_y\sigma_y$ (weighted elasticities of substitution) and $\phi = k_{ax} - k_{ay}$, a "factor intensity coefficient." E_x is the total own-price elasticity of supply of x.

Although equation (21) looks somewhat forbidding, it can be simplified greatly by means of additional assumptions about the parameters. If both x and y have the same factor intensity, so that $k_{ax} = k_{ay}$ (which implies $\alpha_x = \beta_x$ and $\phi = 0$),[2] equation (21) becomes

$$(22)\quad E_x = \frac{e_ae_b + \sigma'(k_{ax}e_a + k_{bx}e_b)}{\alpha_x(\sigma' + k_{bx}e_a + k_{ax}e_b)} - (\alpha_y/\alpha_x)(\eta_y + \eta_{yP_x}).$$

Equation (22) breaks down total supply elasticity into two additive components. The first pertains to factor supply and production conditions, the second to adjustments induced by simultaneous equilibration of the market for y when P_x changes.

The first term, if x is the only product ($\alpha_x = 1$), reduces to the expression for elasticity of supply derived in Muth. The second main term of equation (22) pertains to the feedback effect from the competing commodity y. There are two separate effects, the strength of which is determined by the size of the behavioral parameters, η_{yP_x} and η_y. The effect of the cross elasticity of demand for y with respect to a change in P_x may be illustrated by reference to an example. Let x be soybeans and y be corn. Suppose that P_x increases 10%. Then if $\eta_{yP_x} = 0.3$, the demand curve for corn shifts to the right 3% (i.e., 3% more y is purchased at any given P_y). This shift in demand will discourage resources from going out of corn production into soybeans. Consequently, the rise in soybean production induced by the 10% soybean price increase will be reduced by the cross-demand effect. This is reflected in the fact that the larger is η_{yP_x}, the smaller is E_x in equation (21) or (22).

The effect of the own-price elasticity of demand for the competing product, η_y, is independent of the cross-effects just discussed. Even if η_{yP_x} equals zero, so that the demands for x and y are independent, competing products still have an effect on supply elasticity. Consider a case in which x represents soybeans and y cotton. When the price of soybeans increases 10%, this increases input prices and hence costs of producing the alternative crop, cotton. Consequently, the quantity of cotton produced is reduced, the amount depending on the own-price elasticity of demand for cotton, η_y. Since less y production means less resources used in the y industry, more are available for x production, and the

[2] Relative factor intensity of the two products can be defined equivalently in terms of either factor. The basic definition of ϕ is $\phi = k_{ax}k_{by} - k_{bx}k_{ay}$; but, using the fact that the factor shares for each commodity sum to 1, this can be simplified to either $\phi = k_{ax} - k_{ay}$ or $-\phi = k_{bx} - k_{by}$.

To see that $k_{ax} = k_{ay}$ implies $\alpha_x = \beta_x$, note that equal factor shares implies equal ratios of factor quantities, because factor prices are the same for both products. Graphically, this is a point on the diagonal between 0_x and 0_y in a box diagram such as figure 1. In such a position if x is using, say, 30% of the total a available, x must also be using 30% of b, i.e., $\alpha_x = \beta_x$.

increase in x output is greater than would have taken place if the reduction in y output had not occurred. This is reflected in the fact that the larger (more negative) is η_y, the larger is E_x in equation (21) or (22).

Note that while the two feedback effects from the y industry have opposite effects on E_x, it is normally the case that η_y exceeds η_{yP_x} in absolute value (from homogeneity of degree zero in all prices and income in the demand function for y).[3] Therefore, the second additive term of equation (22) normally will be positive.

Cross-Commodity Price Effects

The magnitude of the effect of a change in one product's price on the other can be expressed as the elasticity $E_{P_yP_x}$, which is one of the variables in equation (20). Solving the system yields

$$(23)\quad E_{P_yP_x} = \{\alpha_x k_{ay} e_b + \beta_x k_{by} e_a + \beta_x \alpha_x \sigma_x + (\beta_x \alpha_y k_{by} + \beta_y \alpha_x k_{ay})\sigma_y - (\beta_x - \alpha_x)\phi\eta_{yP_x}\}/D,$$

where D is the denominator of equation (21). Like (21), equation (23) is greatly simplified under particular assumptions. The most noteworthy case is that if both products have the same factor intensity, i.e., each uses the same fraction of both inputs ($\alpha_x = \beta_x$ and $k_{ax} = k_{ay}$), then $E_{P_yP_x} = 1$. In this case, any demand-side event that increases P_x will increase P_y by the same percentage. The economic meaning of this result is that with CES production functions having equal factor intensities, the relative prices of the two goods are cost-determined and are independent of demand. Given an initial shift in demand for either product, the equalization of opportunity costs will result in a new equilibrium at unchanged relative product prices. This result is the two-product analog of perfectly elastic supply in a single-product model.

[3] The implication of homogeneity is

$$\eta_y = -\eta_{yP_x} - \sum_j \eta_{yP_j} - \eta_{yI}$$

where the η_{yP_j} are cross elasticities of demand for y with respect to prices of other products (besides x and y), η_{yI} is the income elasticity of demand for y. In order for $\eta_y + \eta_{yP_x}$ to be positive, it must be the case that either other goods (j) are gross complements in demand with y or that y is an inferior good.

Elasticity of Transformation

Another way to describe the case when $E_{P_yP_x} = 1$ is to say that the production possibilities curve (PPC) is linear, or that the elasticity of transformation (in Powell and Gruen's terminology) is infinite. The elasticity of transformation in this model is

$$(24)\quad \tau = (E_x - E_{yP_x})/(E_{P_yP_x} - 1).$$

The value of τ is determined by the same parameters which determine E_x. Equation (24) yields a total elasticity of transformation. It differs from movement along a PPC in that input quantities are permitted to change such that input markets are simultaneously equilibrated as P_x changes. The present model differs from a two-good version of Powell and Gruen's constant elasticity of transformation (CET) approach in that (a) input supplies are here allowed to vary according to equations (5) and (6), (b) the elasticity of transformation is not constant here, (c) production is nonjoint, as described in equations (3) and (4).

The difference (a) is eliminated by allowing e_a and e_b to be zero in equations (21), (23), and (19), and inserting the results in equation (24). When $E_{P_yP_x} \to 1$, equation (24) shows that $\tau \to \infty$. With respect to (b), we know that τ will not be constant because at different points on the PPC, α_x and α_y, if nothing else, will differ.

With respect to (c), nonjoint production does not in itself place seriously unrealistic conditions on the PPC. To illustrate graphically the production side of the present model [equations (3) through (10)], figure 1 shows the results of two Cobb-Douglas production functions with a and b fixed (i.e., $e_a = e_b = 0$). Input fixity allows the use of $a = a_x + a_y$ and $b = b_x + b_y$, which can be represented diagrammatically by a box diagram in which each point represents a possible allocation of the inputs to the products. The efficiency locus (or contract curve) shown is the set of points where equations (7) to (10) all hold; it is the set of points where the isoquants for x and y production are tangent.

The box diagram assumes $a = 100$ and $b = 150$. The corresponding PPC is the solid curve in the right-hand panel of figure 1. For example, points S and T on the PPC represent the same allocation of inputs to the two products as S and T in the box diagram. The elasticity of transformation pertains to the shape of the

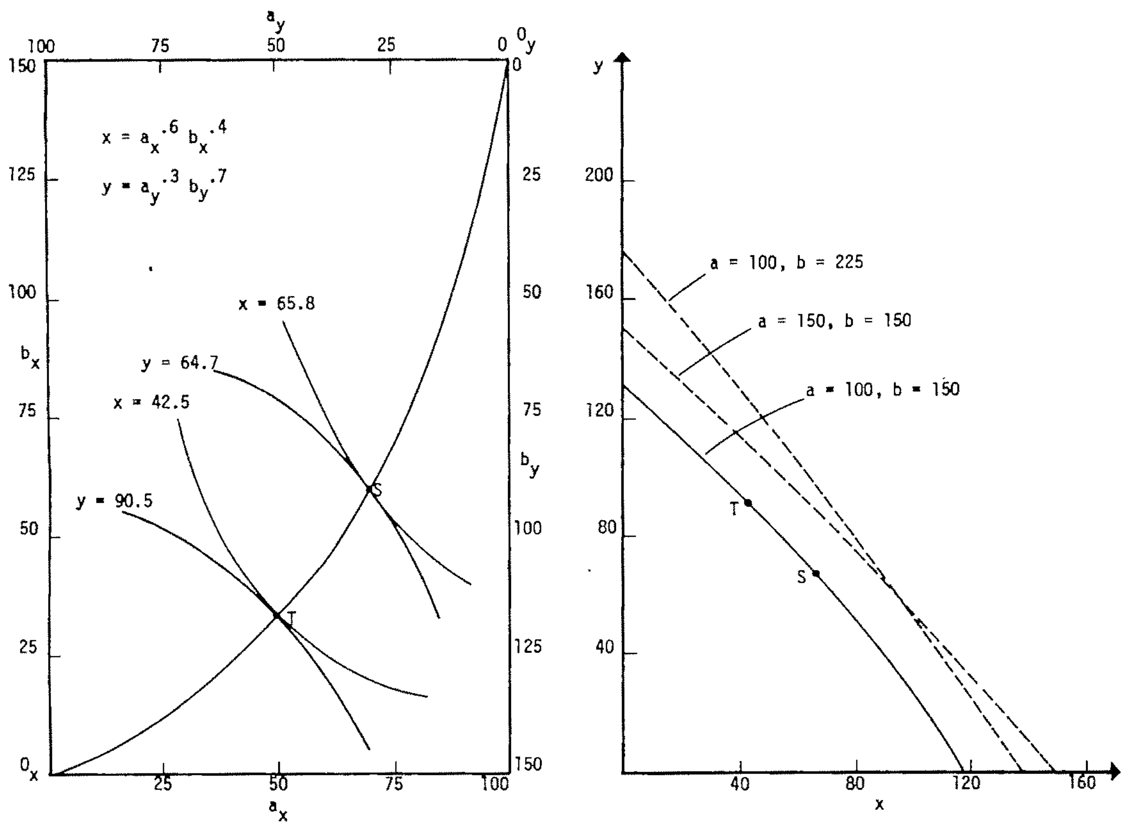


Figure 1. Production functions and production possibilities

PPC. The dotted PPCs show the effects of increased input availability (increasing the size of the box). When the quantity of b increases, production of y, which is b intensive relative to x, is encouraged. Conversely, when the quantity of a increases, the PPC shifts further along the x axis. When product price increases and input supplies are not fixed, then more inputs will be drawn into x and y together and the PPC will shift. But exactly how depends on the supply elasticities e_a and e_b. The total elasticity of transformation involves both a movement along and a shift in the PPC. The supply elasticity of this paper can be thought of as the result of three separate movements: a movement along a PPC to keep VMP/factor price ratios in equilibrium, a shift of the PPC to take account of factor supply changes, and a movement along the new PPC to the point at which the product price ratio clears the market as determined by product demand conditions.

Cross-Elasticity of Supply

The effect of a change in P_x on the quantity produced of y can be derived by substituting equation (23) into equation (19). An interesting special case occurs when factor intensities are the same in x and y, the cross elasticity of supply becomes

$$E_{yP_x} = \eta_y + \eta_{yP_x}. \tag{25}$$

In this case the cross elasticity depends entirely on demand-side parameters. This cross elasticity typically will be negative because η_y typically exceeds η_{yP_x} in absolute value, as discussed above.

The economics of the negative cross elasticity is basically that an increase in a product's price increases returns to resources so that they are bid away from alternative products. However, when less of the alternative product is produced, its price in turn will rise. Since both product prices rise, how do we know that resources will not be drawn into the industry such that production of both products rise when the demand for one of them increases? The reason is that when the demand for the alternative product is stable, the market can only clear at higher prices with less of the alternative product being produced.

The exceptional case in which E_{yP_x} can be positive requires that x and y be substitutes in consumption. A positive partial cross elasticity of demand is not sufficient for a positive E_{xP_y}, however. It is also necessary that y be relatively intensive in the use of the input which is most elastic in supply. As an illustrative example, let x be vegetable oils and y be animal fats. Vegetable oils are relatively intensive in the use of land ($k_{ax} > k_{ay}$), which is inelastic in supply. Suppose the values of the relevant parameters are $e_a = .2$, $e_b \to \infty$ (nonland input perfectly elastic in supply), $k_{ax} = .6$, $k_{ay} = .2$, $\eta_y = -.8$, and $\eta_{yP_x} = .5$. Then the cross elasticity is .23, i.e., a 10% increase in the price of vegetable oils increases the output of animal fats 2.3%.

Aggregate Supply Elasticity

Aggregate output is defined as a weighted sum of the two products,

$$Q = W_x X + W_y Y. \tag{26}$$

The weights are the initial values of P_x and P_y. Differentiating Q with respect to P_x and converting to elasticities,[4]

$$E_{QP_x} = k_x E_x + k_y E_{yP_x}. \tag{27}$$

Substituting equations (21) and (25) into (27) yields messy results, but, again, the case in which factor intensities are equal is much simpler. The aggregate elasticity of supply in this case is

$$E_{Q,P_x} = \frac{e_a e_b + \sigma'(k_{ax}e_a + k_{bx}e_b) + \alpha_y \sigma_y \phi(e_b - e_a)}{\sigma' + k_{bx}e_a + k_{ax}e_b}. \tag{28}$$

In equation (28) the demand parameters drop out.

The aggregate supply response is typically much smaller than the total elasticity of supply E_x because the supply of both products can be increased only by bringing more resources into the industry.[5] As an example, suppose that a wheat crop failure abroad raises U.S.-expected producer price by 10%. Assume that the main alternative use of wheat land is feed grains, wheat initially accounts for one-third of the value of all grains, and the elasticity of demand for feed grains is -0.5. On the production side, assume that inputs may be divided into land and nonland inputs, with land less elastic in supply ($e_a = .1$ and $e_b = .3$), and with land and nonland inputs somewhat substitutable ($\sigma = .5$). Land's share of costs is .30 for wheat but .20 for feed grains (because of more intensive use of fertilizer and pesticides on corn). Given these illustrative parameter values, equation (21) indicates that the production of U.S. wheat should increase 11.7% ($E_x = 1.17$) while equation (24) indicates that feed grains are reduced by 4.7% ($E_{yP_x} = -.47$). The corresponding effect on production of all grains, from equation (27), is $E_{QP_x} = 0.23$. The preceding calculations show the results of interdependent production when the products are independent on the demand side ($\eta_{yP_x} = 0$). Again as an illustration, let wheat and feed grains be substitutes in consumption such that $\eta_{yP_x} = .3$. Then we get the results that $E_x = 0.78$ and $E_{yP_x} = -.18$. Both elasticities move closer to zero. The aggregate supply elasticity, however, remains at 0.23. Note also that as the relative importance of x in the aggregate Q increases (i.e., k_x increases), E_{yP_x} approaches zero and E_x approaches E_{QP_x}.

Applications

Changes in support prices under commodity programs, e.g., the grain and cotton target prices in the Food and Agriculture Act of

---

[4] This result depends on the use of a price-weighted quantity index of aggregate output. From equation (26),

$$\frac{dQ}{dP_x}\frac{P_x}{Q} = \frac{W_x dx}{dP_x(W_x x + W_y y)} + \frac{W_y dy}{dP_x(W_x x + W_y y)}.$$

Let $k_x = x\bar{P}_x/(x\bar{P}_x + y\bar{P}_y)$ and $k_y = y\bar{P}_y(x\bar{\bar{P}}_x + y\bar{P}_y)$. Since $W_x = \bar{P}_x$ and $W_y = \bar{P}_y$, we have $W_x x + W_y y = \bar{P}_x x/k_x = \bar{P}_y y/k_y$, so that

$$\frac{dQ}{dP_x} \cdot \frac{P_x}{Q} = \frac{P_x dx P_x k_x}{dP_x P_x x} + \frac{P_x dx P_y k_y}{dP_x P_y y},$$

which reduces to equation (27).

[5] Note that when $e_a = e_b = 0$, equation (28) is zero. A change in Q is essentially an outward shift of the PPC, so it is natural that (28) is zero. However, the general form ($\phi \neq 0$) of equation (27) is not zero even when inputs are fixed in supply. The reason is an index number problem. When P_x changes, we move along the PPC. With aggregate output defined in terms of initial prices, we obtain an increase in measured output. If the PPC is highly nonlinear, the bias can be considerable. There is no bias in equation (28) because under the simplifying assumption that $\phi = 0$ (or $k_{ax} = k_{ay}$), the PPC is linear as discussed above. For the calculations in table 2, the "Laspeyres" price weights described in footnote 4 were not used, but instead the mean of initial and ending k_x and k_y shares.

1977, should tend to generate supply effects. How can the elasticities developed in this paper help in assessing the likely response? The answer is not as straightforward as one might expect, for two main reasons. First, the programs are often administered such that nonprice constraints such as set-asides accompany the target price. Consequently, the established price alone misrepresents the net production incentives of the program. Second, and more fundamentally, a support price is not a fixed price to producers. It eliminates the lower part of the price distribution. A proper analysis of supply response should take into account the change in price variance as well as the mean price under the program.

While these factors should be taken into account so far as possible, they do not imply that deterministic supply elasticities are of no use in assessing program effects. Nonprice constraints can sometimes be modeled to generate a simple transformation of the supply function to account for program effects.[6] Risk poses greater difficulties, but one can resort heuristically to a separation of expected-price and risk effects on supply. For example, one estimates the effect of a target price increase on mean price, and runs this increase through the deterministic supply elasticity. Risk effects, if they can be estimated accurately enough to be usable, would be a separately additive effect. For the near-term future, this kind of procedure is likely to continue as the only empirically operational approach.

Given that policy analysis, as well as forecasting the effects of other exogenous shocks to the system, can make use of deterministic supply elasticities, why not rely on direct econometric estimates of elasticities and cross elasticities rather than the indirect calculations based on equations like (21) to (28)? In most instances, the direct approach is probably preferable. However, sometimes there do not exist reliable direct econometric estimates of supply elasticities. It is especially difficult to estimate own-price and cross elasticities simultaneously, because commodity prices tend to move together. Moreover, even when we do have econometric estimates, the formulas of this paper may be useful in judging consistency with our knowledge of the relevant input markets. The question arises, however, whether the information available to fill in the right-hand side of equations (21) to (27) is of sufficient quality. For some parameters, such as factor shares, the data may be good; for others, not so. The issue then becomes how sensitive the implied supply elasticities are to parameter values on the right-hand side which cover the range of our uncertainty. This issue is explored further below.

Griliches made use of an indirect method to estimate aggregate supply elasticity. His formula, in the context of a two-input model, is

$$E_x = k_a E_{aP_x} + k_b E_{bP_x}. \tag{29}$$

Here, E_{aP_x} and E_{bP_x} measure the percentage change in a and b used in response to a given change in P_x. They can be analyzed as functions of underlying behavioral parameters as has been done by Floyd, who found

$$E_{aP_x} = \frac{(\sigma + e_b)e_a}{\sigma + k_b e_a + k_a e_b}, \tag{30}$$

$$E_{bP_x} = \frac{(\sigma + e_a)e_b}{\sigma + k_b e_a + k_a e_b}. \tag{31}$$

Substituting equations (30) and (31) into (29) yields

$$E_x = \frac{e_a e_b + \sigma(k_a e_a + k_b e_b)}{\sigma + k_b e_a + k_a e_b}, \tag{32}$$

which is the formula for supply elasticity given by Muth. The parameters are as defined in table 1, with x subscripts omitted. Both the Griliches and Muth formulations are special cases of equation (21), with $\alpha_x = \beta_x = 1$; i.e., equation (21) is a two-commodity analog of equation (32). Equation (29) has been applied to the estimation of supply elasticity more often than equation (32). The reason seems to be that researchers have felt more confident about their estimates of input use in response to product prices than about the own-price elasticity of supply of inputs. Also, equation (29) can be extended to more than two inputs more easily than equation (32). Nonetheless, there are pitfalls in the use of equation (29). The main one is that E_{aP_x} and E_{bP_x} are total, not partial, elasticities in the sense that all other prices are not held constant while P_x changes. In particular, input prices are not held constant. Therefore, it is inappropriate to use estimates of E_{aP_x} and E_{bP_x} from regression

[6] For example, Gardner (pp. 10–14) shows how the basic incentives established by the 1978 wheat program can be expressed by replacing expected market price with the expression for marginal revenue which is linear in expected market price and program variables.

equations which hold P_a and P_b constant (unless, of course, P_a and P_b actually are constant in the context being studied). The studies using the indirect approach (Griliches; Heady and Tweeten, pp. 434–35; Tweeten and Quance, pp. 350–51) in fact do hold input prices constant and for that reason yield questionable results which should tend to overstate aggregate supply elasticity.[7]

While the preceding approaches are useful in considering agriculture as a sector, for the analysis of supply of particular products it is important to consider substitution among products by farmers. Indeed, equation (32) implies that if inputs are fixed in supply ($e_a = e_b = 0$), then the elasticity of product supply (E_x) is zero; whereas, in practice the short-run supply response that is most important does not involve shifts of inputs into or out of aggregate agricultural production, but instead shifts of inputs from one farm product to another. It is in this context that equation (21) may prove helpful.

In order to gain an improved understanding of the anatomy of supply elasticity with product interdependence, table 2 shows the elasticity of supply as given by equation (21) under various parameter values. This exercise will be useful in suggesting which of the underlying behavioral parameters are likely to be most important in determining supply elasticity.

Let the factor a represent cropland and b an aggregate of all other inputs used in crop production. For concreteness, production parameters (factor shares) are used for the High Plains of Texas as estimated by the Texas Agricultural Extension Service for cotton and grain sorghum. These are the main competing crops in much of this area. Let x be grain sorghum and y cotton. The question is, what will be the effect of an increase in the price of grain sorghum (due to an increase in target prices, say)?

The following parameter values are used: elasticity of supply of cropland e_a, is 0.1; the fraction of costs of grain sorghum accounted for by the rental value of land, k_{ax}, is 0.3; the fraction of costs of cotton accounted for by land, k_{ay}, is 0.2; the elasticity of supply of nonland inputs, e_b, is 0.25; the elasticity of demand for cotton, η_y, is -0.5; the elasticity of demand for cotton with respect to the price of grains, η_{yP_x}, is zero; the fraction of the grain and cotton land accounted for by grain, α_x, is 0.5; sorghum's share of nonland inputs, β_x, is 0.4; and the elasticities of substitution, σ_y and σ_x, are both taken to be equal to 0.5. Line 1 of table 2 shows the value of the elasticity of supply of grain sorghum implied by the parameter values, calculated according to equation (21). It is 1.10.

While the parameter values are "ballpark" estimates that roughly fit the situation in parts of the High Plains of Texas, some of the estimates are shaky. It is, therefore, instructive to consider what happens to supply response as certain parameters vary from the values assumed above. Line 2 shows what happens to the elasticity of supply of grain with a fixed quantity of land ($e_a = 0$). Even when land is fixed in supply, the elasticity of supply of grain is substantial because land comes out of other crops and because other inputs substitute for land.

[7] To get a feel for the magnitude of error caused by holding input prices constant, consider the following example. Let $e_a = e_b = 0.5$, $\sigma = 1$, and $k_a = k_b = 0.5$. Then $E_{aP_x} = E_{bP_x} = e_x$, which implies that $e_x = 0.5$. However, if P_b is held constant in a regression procedure to estimate E_{aP_x}, an estimate results which yields an elasticity of product supply of 0.75. And if we had also used this same regression procedure to estimate E_{bP_x}, our estimate of e_x would be 1.0, twice its true value. In general, this approach will tend to overstate product supply elasticity.

Table 2. Elasticity of Supply under Various Conditions

	Given Parameter Values[a]							Elasticity of Supply, E_x, from
	e_a	e_b	η_y	η_{yP_x}	σ_x	α_x	β_x	Equation (21)
1. Base case	.1	.25	−.5	.0	.5	.4	.5	1.10
2. Fixed land	.0	.25	−.5	.0	.5	.4	.5	0.98
3. Fixed nonland inputs	.0	.0	−.5	.0	.5	.4	.5	0.69
4. Single product	.1	.25	−.5	.0	.5	1.0	1.0	0.20
5. Inelastic alternative crop demand	.1	.25	−.25	.0	.5	.4	.5	0.79
6. Products substitute in demand	.1	.25	−.5	.2	.5	.4	.5	0.84
7. Zero elasticity of substitution	.1	.25	−.5	.0	.0	.4	.5	0.89

[a] k_{ax} = .3 and k_{ay} = .2 throughout.

The elasticity of supply of nonland inputs also plays an important part in supply theory—e.g., the idea that supply response to a fall in price is small (at least for a period of several years) because of fixed investments in capital equipment which it is cheaper to use than abandon or sell at salvage value. This idea is incorporated in table 2, line 3, by calculating the elasticity of supply with $e_b \rightarrow 0$. Although the elasticity of supply is much reduced in this case, it is still positive when land and other inputs can be shifted from one crop to another. Of course, if the demand for all crops declines, this avenue of substitution is not available.

The elasticity of product supply exceeds the elasticity of supply of any of the inputs because of shifts in all inputs from one product to the other. Two facts about this substitution are derivable from equation (21).

First, the scope for supply response by crop substitution is less, the more important is the crop in an area's agricultural production, i.e., the larger are α_x and β_x. Line 4 shows what happens when they equal 1, a single-product case. The elasticity of supply is reduced substantially. Second, supply response by product substitution depends on the demand function for the competing products. If the demand function for cotton is less elastic, resources will be displaced from cotton production when grain prices rise because only a little less cotton production will increase cotton prices enough to maintain equilibrium between the enterprises. This is seen in line 5 of table 2 by letting η_y be -0.25 instead of -0.5. In general, E_x is greater the greater is $|\eta_y|$.

It is probably reasonable to assume that the effect of an increase in the price of grain on the demand for cotton is negligible ($\eta_{yP_x} = 0$). If it were not, however, it would affect supply response. Suppose we were considering the production of grains in Illinois, where the principal substitute crop is soybeans. A rise in the price of grains would increase the demand for soybeans, thus tending to hold resources in soybean production. Line 6 of table 2 explores this possibility by increasing η_{yP_x} to 0.2, holding the other parameters the same as the base case. The supply response of soybeans to increased prices is especially interesting because the main substitute on the supply side, corn, is also a substitute on the demand side. This is an additional reason for the total elasticity of supply of soybeans to be much smaller than the partial equilibrium supply elasticity. This example suggests that the inclusion of η_{yP_x} in equation (21) in some cases will be empirically important.

The main parameter remaining to be discussed is one on which our knowledge is likely to be poor, the elasticity of substitution between inputs a and b in x and in y production. In line 7 of table 2, σ_x and σ_y are set equal to zero. Comparing lines 1 and 7 shows how the absence of possibilities for substitution in production changes product supply elasticity. However, if the input supply elasticities were the same ($e_a = e_b$), the change to fixed proportions would make no difference in the elasticity of supply, suggesting that the inclusion of σ in the model has little practical importance. The reason is that substitution has no scope to operate when the elasticities of supply of both inputs are the same because under these circumstances demand shifts do not generate relative factor-price changes.

The role of the elasticity of substitution is noteworthy because if $\sigma = 0$, then a linear programming approach with one activity per commodity is appropriate for simulating supply response, while if $\sigma \neq 0$ it is not. If the elasticity of supply is insensitive to the value of σ, there is little harm in using the programming approach even if in fact $\sigma \neq 0$. While E_x is not very sensitive to σ in table 2, σ is quantitatively important in determining product supply response to price in other cases, particularly if the factor shares differ substantially. It is fortunate that E_x is often not sensitive to σ because our information about this parameter is usually not solid. In the grain sorghum/cotton case, the elasticity of substitution between land and other inputs may well be higher under irrigated than dryland production (because a wider variety of yield-increasing techniques may be used). But even if σ is 1.0 instead of 0.5, the implied value of E_x changes only from 1.10 to 1.13.

Finally, consider the role of the relative factor-intensity of the two products, as measured by ϕ (which is the difference between factor shares for the two products, i.e., $k_{ax} - k_{ay}$ or $k_{by} - k_{bx}$) in equation (21). The most interesting theoretical aspect of ϕ is that it introduces the possibility that the alternative product's price can rise by a larger percentage than the price rise in the first product ($\%\Delta P_y > \%\Delta P_x$), a case which appears to create the possibility of a negative total elasticity of supply. If a product is relatively intensive in the use of an input whose supply is relatively elas-

tic, i.e., $k_{ax} > k_{ay}$ and $e_a > e_b$, then the term containing ϕ is negative. For example, consider tobacco, which is relatively intensive in the use of nonland inputs (labor) which are relatively elastic in supply. If the tobacco price increases due to increased demand, the relative price of land will increase assuming land is less elastic in supply. Because other crops are relatively intensive in land use, the cost of producing them will increase more than the cost of producing tobacco, so that the price of other crops relative to tobacco will increase. The higher relative price of land encourages substitution of nonland for land inputs in nontobacco crops. [Note that if $\sigma_y =$ 0, the ϕ term of equation (21) is zero.] This will tend to draw nonland inputs out of tobacco production and, therefore, to reduce tobacco production. Thus, the positive supply response of tobacco production to price is reduced.

It is not possible, however, for this negative effect to offset the other terms of equation (21) to generate a negatively sloped supply curve. To show this, consider the case most favorable to a negative supply elasticity, with $\eta_y = 0$, $\sigma_x = 0$, $e_a = 0$, and $e_b \rightarrow \infty$. In this case, equation (21) becomes

$$E_x = \frac{k_{bx}\sigma_y + \alpha_y\sigma_y(k_{ax} - k_{ay})}{\alpha_x k_{ax}}.$$

Substituting $k_{bx} = 1 - k_{ax}$ the equation reduces to

$$E_x = \frac{(1 - k_{ay}\alpha_y)\sigma_y}{\alpha_x k_{ax}},$$

which is positive.

Specific Factors and Length of Run

The table 2 examples suggest total supply elasticities somewhat higher than one might expect from the existing econometric evidence on grains. On the other hand, the examples also suggest why the econometric evidence from equations containing more than one commodity price is not as solid as might be hoped; namely, the cross-price elasticity is 0.9 or more in all the cases considered. An exogenous shift of demand for x will increase P_y at least .9 of the increase in P_x. Therefore, serious colinearity of prices is to be expected in empirical data.

Nonetheless there is a reason why the model of this paper may tend to overstate total supply elasticity. It is the assumption that the two products use exactly the same inputs, albeit in different proportions. In reality, there are likely to be inputs specific to each commodity, especially in the short run. For example, while it may be appropriate to consider a general input called "capital" to be allocated to grain sorghum or cotton in the long run, in the short run there are inputs like cotton-harvesting machinery which are specific factors of production—used for one commodity but not the other.

A relatively simple extension of the model of equations (1)–(10) is to replace the input b in the commodity y by a specific input c, so that each product uses the common input a and a second input (b in x and c in y). The supply function of c is added as an additional equation. In this case, when P_x rises, the induced increase in price of the specific factor does not affect the cost of producing the alternative product. Therefore, fewer resources move out of y into x (E_{yP_x} is closer to zero) and x production does not increase as much (E_x is smaller). As an illustrative example, using the same parameters as in line 1 of table 2, if factor b were specific to x production and y production involved a specific factor c with the same factor shares and supply elasticity as b, then the value of E_x is reduced from 1.10 in line 1 to 0.35 and the cross elasticity E_{yP_x} is increased from −.47 to −.06. This example is an extreme one in that the specific factors account for 70% of the cost of x and 80% of the cost y, while the common factor a accounts for only 30% and 20% of costs. A lesser relative importance of specific factors makes the contrast much less strong.

Effect of Factor Price Change on Production

The two-product, two-input model is helpful in analyzing an issue closely related to but distinct from the main subject of this paper—the response of production to a factor price change. In a single-product model, an exogenous increase in an input price always increases product price and reduces production. But in a two- (or more) product case, an input price increase can result in more of one of the products being produced. An interesting example is provided by Swanson and Taylor. In

their model an increase in energy price increases the production of soybeans. The essential reason is that corn is relatively energy-intensive, so that land shifts out of corn to a next-best alternative of soybeans (or other crops) even though it is more expensive to produce these other crops, too. An immediate implication is that because more soybeans will only clear the market at a lower price, other inputs, presumably land, must fall in price by more than enough to offset the cost increase caused by higher energy prices.

These propositions may be derived formally in terms of a fixed proportions version of the basic model used to derive equation (4) (to be consistent with Swanson and Taylor who use a linear programming model). The effect of a given percentage change in price of an input, P_a, on the outputs of the products, x and y, are:

$$(33) \quad E_{xP_a} = \frac{\eta_x k_{ax} e_b - \phi\beta_y\eta_y}{e_b - k_{bx}\beta_x\eta_x - k_{by}\beta_y\eta_y},$$

$$(34) \quad E_{yP_a} = \frac{\eta_y k_{ay} e_b + \phi\beta_x\eta_x}{e_b - k_{bx}\beta_x\eta_x - k_{by}\beta_y\eta_y},$$

where the variables are as defined in table 1. All the denominator terms are positive. Often both numerators would be negative so that E_{xP_a} and E_{yP_a} are negative—higher input prices generate production cutbacks.

However, in certain cases the sign is reversed. Let P_a be the price of energy and P_b the price of other inputs (principally services of land). Let the product x be corn, which is energy-intensive relative to soybeans, with $k_{ax} = 0.5$, $k_{ay} = 0.2$. Let the elasticity of supply of land be zero, the elasticity of demand for corn be −.40 and the elasticity of demand for soybeans be −.67 (values used by Swanson and Taylor), and the relative importance of corn, β_x, be 0.6. Inserting these values in equations (33) and (34) yields $E_{xP_a} = -.096$ and $E_{yP_a} = .144$. An increase in the price of energy reduces the energy-intensive crop output about .1% for each 1% increase in the price of energy, but increases the less energy-intensive crop by .14%. This result is dependent on the low elasticity of supply of alternative inputs, e_b, which "traps" these resources into producing either one crop or the other despite lower returns.[8] If e_b were 0.5 instead of zero and the other parameter values remained the same, E_{xP_a} would be −.19 and E_{yP_a} would be −.02.

A more complete treatment of this issue would require considering equations (33) and (34) for the more general case in which σ_x and σ_y are not zero. This goes beyond the scope of the present paper.

Summary and Limitations

Analysis of supply elasticity based on a single-product model, such as Muth's, has the weakness that for many agricultural products substitution of resources from one commodity to another is more important than bringing new resources into the agricultural sector. But existing multiproduct models, such as that of Powell and Gruen, assume resources to be fixed in supply, which is not correct either. This paper analyzes the total elasticity of supply when there are both alternative products and resources not fixed in supply.

It is found that the total elasticity of supply depends on several factors.

(*a*) The elasticity of supply of inputs (e_a, e_b). As in the Muth model, product supply is more elastic, the more elastic are input supply functions. However, unlike Muth's results, even when quantities of resources are fixed, there is still positive output response to product price.

(*b*) The elasticity of demand for alternative products (η_y). Because inputs tend to earn the same returns in all uses, the price of an alternative product goes up when an increase in a first product's price induces input price increases. This results in reduced demand for the alternative product, which releases inputs for use in producing the product whose price originally rose. Consequently, a product's supply is more elastic the more elastic is the demand for alternative products.

(*c*) The elasticity of substitution between inputs in production (σ_x, σ_y). The elasticity of

---

[8] Because more soybeans are produced, they must sell for a lower price, even though energy prices have risen. Therefore, the price of nonenergy inputs must fall. This can be seen formally by deriving the elasticity of P_b with respect to P_a, which is

$$E_{P_b P_a} = \frac{k_{ay}\beta_y\eta_y + k_{ax}\beta_x\eta_x}{e_b - k_{by}\beta_y\eta_y - k_{bx}\beta_x\eta_x}.$$

This equation is always negative. However, it will approach zero as $e_b \to \infty$. The more elastic is the supply of e_b (the less "trapped" are nonenergy inputs), the less the burden imposed on owners of farm inputs b.

substitution becomes more important as changes in product demand change relative input prices, i.e., when e_a and e_b are much different. An increase in σ_x, when it makes a difference, always increases the elasticity of supply of x. An increase in σ_y can either increase or decrease supply elasticity.

(*d*) The relative importance of the commodity in resource use (α_x, β_y). As inputs become more nearly specific factors to x production, a rise in product price more readily increases input prices. Therefore, an increase in α_x or β_x reduces supply elasticity.

(*e*) The factor intensity of a commodity. The importance of factor intensity depends on the factor intensity of other products, the difference in input supply elasticities, and the elasticities of substitution. In general, the more intensive a product is in use of factors relatively inelastic in supply, the smaller the product supply elasticity.

(*f*) The cross elasticity of demand for alternative products with respect to the price of the product whose supply elasticity is being measured (η_{yP_x}). In many cases, this parameter will be of negligible importance, but there are notable instances where products which use the same inputs are also substitutes in consumption, e.g., corn and soybeans. A higher cross elasticity means that when the price of x rises, the demand for the alternative crop increases, keeping resources from x production and hence reducing elasticity of supply of x.

Equation (21) shows how these elements interact in the determination of product supply elasticity. While this equation, of course, is no substitute for econometric work, it may be useful in assessing the reasonableness of regression estimates of supply elasticity by checking for consistency with other information available about the characteristics of the product being studied. The equation may also help in assessing the likely errors introduced by shortcuts necessitated by our inability to estimate models which treat all prices as endogenous. For example, in estimating supply functions there are usually not reduced-form equations for inputs or for substitute products. Instead, factor prices (or quantities) and alternative product prices are held constant in time-series regressions or else used as deflators, thereby yielding partial elasticities of supply which give biased estimates of how output actually would change due to an exogenous product-price change. Equation (21) can indicate the likely magnitude of such bias. Similarly, when a linear programming approach is used to simulate supply response, equation (21) allows one to calculate the probable error introduced by the assumption of fixed proportions in production or fixed resource supplies or other simplifying assumptions that the simulation may incorporate. Moreover, equation (21) itself provides an alternative simulation tool.

With respect to cross-price elasticities, equations (23) and (28) can perform similar services in helping to form reasonable expectations when econometric evidence is incomplete and in evaluating the specification of econometric models when they are proposed. The model also can be extended readily to analyze the effects of exogenous factor price changes on product prices, as in equations (33) and (34).

Two important limitations of the model are its restriction to two products and two inputs and the lack of distinction between short- and long-run response to price. The latter problem can be remedied partially by choice of parameters for elasticity of input supply and product demand to fit the context being considered. The model shares with corresponding single product models (Muth, Floyd) the limitations of assuming constant returns to scale, competition in product markets, and equilibrium in factor markets. And, like all deterministic supply models, it neglects the role of uncertainty. Notwithstanding these serious limitations, the analysis can be helpful in understanding and interpreting some aspects of supply behavior in interdependent markets.

[*Received May 1978; revision accepted November 1978.*]

References

Buse, Reuben C. "Total Elasticities—A Predictive Device." *J. Farm Econ.* 40(1958):881–91.

Floyd, John E. "The Effects of Farm Price Supports on the Return to Land and Labor in Agriculture." *J. Polit. Econ.* 73(1965):148–58.

Gardner, Bruce L. "Economic Consequences of the 1977 Farm Bill." Dep. Info. Rep., Texas A&M University, March 1978.

Griliches, Zvi. "The Demand for Inputs in Agriculture and a Derived Supply Elasticity." *J. Farm Econ.* 41(1959):318–22.

Hall, Robert E. "The Specification of Technology with Several Kinds of Output." *J. Polit. Econ.* 81 (1973): 878–92.

Heady, Earl O., and Luther Tweeten. *Resource Demand and Structure of the Agricultural Industry*. Iowa State University Press, Ames, 1962.

Johnson, H. G. *The Two-Sector Model of General Equilibrium*. Chicago: Aldine Publishing Co., 1971.

Muth, Richard F. "The Derived Demand Curve for a Productive Factor and the Industry Supply Curve." *Oxford Econ. Pap.* 16(1965):221–34.

Powell, Alan A., and J. H. Gruen. "The Constant Elasticity of Transformation Production Frontier and Linear Supply System." *Int. Econ. Rev.* 9(1968):315–28.

Swanson, E. R., and C. R. Taylor. "Potential Impact of Increased Energy Costs on the Location of Crop Production in the Corn Belt." *J. Soil and Water Conserv.* 31(1976):126–29.

Tweeten, Luther, and Leroy Quance. "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches." *Amer. J. Agr. Econ.* 51(1969):342–52.

Endogenous Input Prices in Linear Programming Models

Peter B. R. Hazell

This paper provides a method for formulating linear programming models in which one or more factors have upward sloping supply schedules, and the prices of these factors are to be endogenously determined at either their competitive market equilibrium values or at the levels set by a monopsonist. The method for achieving these results utilizes the sum, over the relevant factor markets, of the producers' and consumers' surplus, and is an extension of existing methods for solving price endogenous models of product markets.

Key words: competitive market equilibrium, factor markets, linear programming, monopsony.

Mathematical programming methods to solve competitive market equilibria problems are available in the literature. Samuelson provided the basic methodology for achieving this by utilizing the sum of consumers' and producers' surplus as the model maximand. He developed this result in the context of spatial equilibrium models in which the market supply and demand schedules are given exogenously. Takayama and Judge (1964, 1971) extended the approach to multimarket equilibria using quadratic programming. Duloy and Norton (1973, 1975) subsequently modified Takayama and Judge's work for use with agricultural sector models in which the product demand schedules are given exogenously, but in which the supply schedules are portrayed implicitly by production decision models. They also showed how the problem could be linearized efficiently to solve large-scale models with standard linear programming routines. Subsequently, Hazell and Scandizzo (1974, 1977) generalized their model to obtain competitive market equilibria when yields are risky and producers act in risk-averse ways.

While the literature has focused on obtaining competitive equilibria in product markets, the same methodological approach is also relevant in principle for solving factor market equilibria when the supplies of inputs are represented by increasing cost functions. A problem of this kind concerns the specification of the supplies of labor in models of agricultural production at regional or sector-wide levels. Often, farm family labor is specified to be available at a zero, or a positive but fixed reservation wage, and additional supplies of labor from seasonal or migrant workers are specified as available for hire at higher wages, and which may be fixed or specified as increasing functions of the amount of labor hired. An increasing wage function can be specified as continuous (e.g., Hazell), or, more commonly, different sources of labor are recognized and their supplies defined as a step function in which each type of labor becomes available as a specified minimum wage (e.g., Kutcher and Scandizzo).

The purpose of this note is to extend the Duloy-Norton method to obtain the solution to endogenous factor markets in aggregate agricultural production models. In this case, it is the factor supply function that is given exogenously, and the factor demand function which is implicitly contained in the production decision model. The method is first developed using a continuous increasing cost function, and then the special complexities inherent with the use of step functions are considered. As a corollary to this paper, it is shown that the usual method of treating family labor in agricultural models leads to a discriminating monopsonist's solution, but that this can be justified as the relevant specification.

Peter B. R. Hazell is an economist with the Development Research Center of the World Bank.

With the usual caveat, special thanks are due John Duloy, Roger Norton, Wilfred Candler, Johannes Bisschop, and Gerald O'Mara for their comments on earlier drafts of this paper. Views expressed are those of the author and do not necessarily reflect those of the World Bank.

A Basic Model

Consider a profit-maximizing model for a region or sector in which, for convenience, labor is specified as the only critical constraint.

$$\text{(1)} \qquad \text{Max } \Pi = (\mathbf{p} - \mathbf{c})'\mathbf{x} - wL,$$

such that

$$\text{(2)} \qquad \mathbf{d}'\mathbf{x} - L \leq 0,$$

where $\mathbf{x}$ is a vector of output levels, $\mathbf{p}$ and $\mathbf{c}$ are vectors of market prices and direct costs, respectively, $\mathbf{d}$ is a vector of labor requirements and L is the amount of labor used at wage w. If labor has a perfectly elastic supply, then w is fixed and (1) and (2) yield a competitive solution to the allocation of labor.

Monopsonistic Behavior

Suppose now that w is specified as an increasing function of the quantity of labor used, and more specifically, that $w = \alpha + \beta L$. The total wage bill is then $wL = \alpha L + \beta L^2$, and it is tempting to reformulate (1) as

$$\text{(3)} \qquad \text{Max } \Pi = (\mathbf{p} - \mathbf{c})'\mathbf{x} - \alpha L - \beta L^2.$$

However, the solution to (3) and (2) would then provide a monopsonistic allocation of labor in which its marginal value product is equated to its marginal cost, and not to its average cost as is required in a competitive market equilibrium.

This result can be shown from the Kuhn-Tucker conditions for an optimal solution. Forming the Lagrangian function

$$G = (\mathbf{p} - \mathbf{c})'\mathbf{x} - \alpha L - \beta L^2 + \lambda(L - \mathbf{d}'\mathbf{x}),$$

then the relevant necessary conditions are

$$\frac{\partial G}{\partial x_j} = p_j - c_j - \lambda d_j \leq 0, \text{ all } j$$

$$\frac{\partial G}{\partial L} = -\alpha - 2\beta L + \lambda \leq 0.$$

If $L > 0$, then the complementary slackness conditions require that the second condition hold as a strict equality; in which case,

$$\lambda = \alpha + 2\beta L = \frac{\partial wL}{\partial L},$$

the marginal cost of labor. The first set of conditions, which will also hold as strict equalities for $x_j > 0$, then equate the marginal cost of labor (λ) to its marginal value product in the production of each nonzero production activity.

Note that since $w = \alpha + \beta L$, then $\lambda = w + \beta L$. Thus, given the optimal amount of labor used (L^*), the associated market-clearing wage is $w^* = \alpha + \beta L^*$, and this is smaller than λ (the shadow price) by βL^*. Figure 1 portrays the situation.

The demand curve for labor is the implicit marginal value product curve, and the labor supply function is an average cost function, to which corresponds the marginal factor cost function $w = \alpha + 2\beta L$. The optimal value of L^* in model (3) and (2) corresponds to the intersection of the demand and marginal cost curves. The shadow price of labor is then $\lambda = w^* + \beta L^*$, and the corresponding market wage is w^*. Monopsonistic profits to the industry are depicted by the shaded rectangle.[1]

Competitive Behavior

To obtain a competitive solution to the labor market, (wage w_0 and quantity L_0 in figure 1), it is necessary to reformulate the model so as to maximize the area between the labor demand and supply schedules. Now the area under the labor demand function is total income gross of labor costs, i.e., $(\mathbf{p} - \mathbf{c})'\mathbf{x}$ (this being the integral of the marginal value product curve). Further, the area under the labor supply schedule is $\int_0^L (\alpha + \beta L)dL = \alpha L + \frac{1}{2}\beta L^2$. Consequently, the relevant model objective function, which is the difference between these two areas, is

$$\text{(4)} \qquad \text{Max } \phi = (\mathbf{p} - \mathbf{c})'\mathbf{x} - \alpha L - \tfrac{1}{2}\beta L^2.$$

To show that this maximand provides the competitive market equilibrium, consider the necessary Kuhn-Tucker conditions when (4) is maximized subject to (2). These are

$$\frac{\partial G}{\partial x_j} = p_j - c_j - \lambda d_j \leq 0, \text{ all } j,$$

$$\frac{\partial G}{\partial L} = -\alpha - \beta L + \lambda \leq 0.$$

Now if $L > 0$, then $\lambda = \alpha + \beta L = w$, the average wage, and for all $x_j > 0$, the marginal

[1] Given that the model represents an aggregate of many farms, then the solution is really that for a colluding monopsony or cartel.

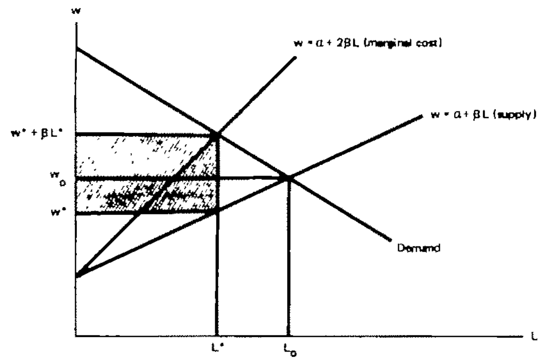


Figure 1. Alternative labor market equilibria

value product of labor is equated to the average wage. Clearly this solution corresponds to the intersection of the supply and demand for labor in figure 1.

Assuming linear supply functions, the extension to multiple factor markets is straightforward. Let the supply system be $\mathbf{W} = \mathbf{A} + B\mathbf{L}$, where $\mathbf{W}$ and $\mathbf{L}$ are $\mathbf{m} \times 1$ vectors of factor prices and quantities of factors hired, respectively, $\mathbf{A}$ is an $\mathbf{m} \times 1$ vector of factor supply intercepts, and B is an $\mathbf{m} \times \mathbf{m}$ matrix of factor supply slope and cross-slope coefficients. Then the relevant objective function for the competitive model is

$$\text{Max } \phi = (\mathbf{p} - \mathbf{c})'\mathbf{x} - \mathbf{L}'(\mathbf{A} + 0.5\, B\mathbf{L}).$$

The resource constraint set for the problem would then include such conditions as $D\mathbf{x} - \mathbf{L} \leq 0$, where D is a matrix of resource requirement coefficients. The derivation of this objective function does require that the B matrix be symmetric, but the existence of off-diagonal elements (implying cross-elasticities between input supplies) can be handled with linear programming using a similar procedure to the Duloy-Norton (1975) treatment of cross-elasticities in demand.

Linear Programming Approximations

The model maximand (4) is quadratic in L, but since it is also concave in L, it can be approximated for linear programming using the technique described by Duloy and Norton (1975). The method is applicable to the term $Q = \frac{1}{2}\beta L^2$, and entails defining new activities y_k, $k = 1, 2, \ldots, K$, such that $\sum_k y_k \leq 1$. Then, to each y_k is associated a value of L, say L_k, such that $L = \sum_k L_k y_k$, and a corresponding value of $Q_k = \frac{1}{2}\beta L_k^2$. Q is then equal to $\sum_k Q_k y_k$.

The model (4) and (2) is then replaced by the approximating model

$$\text{(5)} \quad \text{Max } \phi = (\mathbf{p} - \mathbf{c})'\mathbf{x} - \alpha L - \sum_k Q_k y_k$$

$$\text{(6)} \quad \text{such that } a'\mathbf{x} - L \leq 0.$$

$$\text{(7)} \quad \sum_k L_k y_k - L = 0$$

$$\text{(8)} \quad \sum_k y_k \leq 1.$$

Note that to solve the monopsonist's problem it is only necessary to replace (5) by

$$\text{(9) Max } \Pi = (\mathbf{p} - \mathbf{c})'\mathbf{x} - \alpha L - 2 \sum_k Q_k y_k.$$

An advantage of this linearization technique is that it adds only two constraints to the model, while the number of y_k activities can be made as large as necessary to obtain any desired degree of accuracy. It should be realized, though, that quite a large number of y_k activities may be necessary to obtain acceptably similar values for the dual wage [the shadow price on (6)] and the market wage obtained by solving $w = \alpha + \beta L$ given the optimal value of L. The difficulty can best be demonstrated with the aid of figure 2.

In figure 2(b), the labor supply function $w = 0.5 + 0.05\,L$ has been plotted for the first sixty units of labor, and the area under this line has been plotted with a solid line in figure 2(a). The linearization technique involves approximating the area function in a piecewise linear fashion—the dotted lines in figure 2(a). The average cost function corresponding to the linearized area function is then the dotted step function in figure 2(b). This function has the property that the steps intersect the original labor supply function at their interval midpoints, while the jumps from one step to another occur at interval end points.

Now, the dual wage obtained on the labor constraint (6) will correspond to the value of one of the steps, providing that L is not equal to an interval end point. Furthermore, the dual wage will be exactly equal to the market wage when L is equal to an interval midpoint, but will be smaller (greater) than its market value if L lies to the right (left) of such a midpoint.

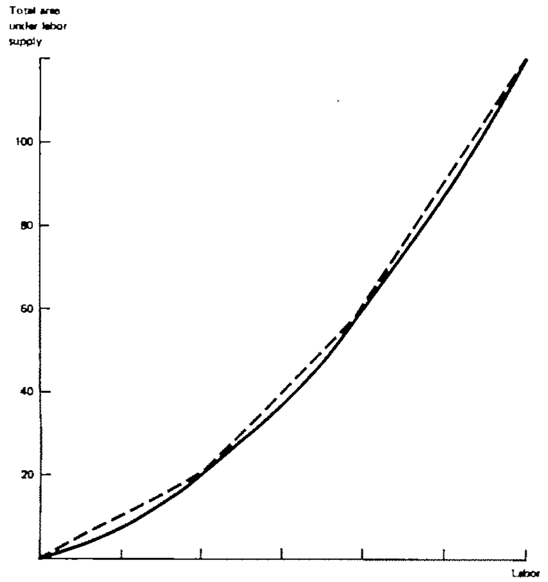


Figure 2(a). **Total area under labor supply**

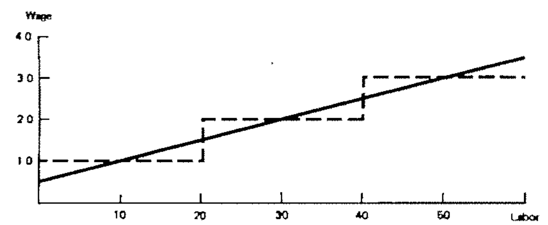


Figure 2(b). Labor supply functions

When L is equal to an interval end point, then the dual wage is degenerate, and it may take on any value defined by the relevant vertical section of the step function. At these end points the discrepancy between the dual and market wages may not only be largest, but if a discrepancy exists it is also unpredictable in sign.

When the dual and market wages obtained from the solution are not equal, then the model solution will not be the desired market equilibrium. Solutions therefore need to be checked for internal consistency, and whenever significant discrepancies occur, a larger number of segments should be created within the relevant neighborhood of optimal L.

A Numerical Example

Table 1 contains a small numerical example of model (5) through (8) which involves three crop activities and constraints on land and labor supplies. The labor supply function is $w = 0.5 + 0.0075\ L$, and the area under this curve has been approximated by creating sixty linear segments over equal intervals of five units of L each. *COMP* is the objective function for the competitive market equilibrium [equation (5)], while *MONP* is the objective function for a monopsonist [equation (9)]. The entries under y_k are therefore $-(0.5)(0.0075)\ L_k^2$ for *COMP*, and $-(0.0075)\ L_k^2$ for *MONP*.

The solutions to the competitive and monopsonistic problems are given in table 2. As should be expected, the monopsonistic solution employs less labor and has a shadow price that is higher than the corresponding market wage. Agricultural income (*MONP*) is thirty-seven units higher in the monopsonistic solution than in the competitive solution. The discrepancy between the market and shadow wages in the competitive solution is due to the linearization technique. In this case $L = 225$ occurs at an interval end point, and the shadow wage is degenerate at that point. In fact, the dual wage could have taken on any value between 2.168 and 2.208.

Stepped Labor Supply Functions

As we have seen, stepped supply functions arise artificially from using linearization techniques (figure 2), but they also arise in reality when different sources of labor are identifiable which can be expected to enter the labor market as the wage reaches critical levels. In either case, the step function corresponds to an average wage schedule, and a competitive market solution is obtainable with model (5) through (8). An alternative approach is to define activities L_k which denote the amount of labor of the kth type entering the market at wage w_k, and then to solve the problem:

$$\text{(10)} \quad \text{Max } \phi = (\mathbf{p} - \mathbf{c})'\mathbf{x} - \sum_k w_k L_k,$$

such that

$$\text{(11)} \quad a'\mathbf{x} - L \leq 0,$$

$$\text{(12)} \quad L_k \leq b_k, \text{ all } k,$$

$$\text{(13)} \quad \Sigma L_k - L = 0,$$

where b_k denotes the amount of labor available of the kth type, and $\Sigma w_k L_k$ measures the area under the labor supply schedule. This formulation is equivalent to (5) through (8) (see, for example, Duloy and Hazell, p. 322) and yields additional, though not very useful,

Table 1. LP Tableau for Numeric Example

Row Name	Crop Production Activities X_1	X_2	X_3	Labor Use L	Activities to Linearize Q y_1	y_2	, . . . ,	y_{59}	y_{60}	Constraint
COMP	15	12	16	−0.5	−0.094	−0.375	, . . . ,	−326.34	−337.5	MAX
MONP	15	12	16	−0.5	−0.188	−0.75	, . . . ,	−652.69	−675.0	MAX
Labor	3	2	2.5	−1						≤ 0
Land	1	0.75	1.25							≤ 100
Labor Indentity				1	−5	−10	, . . . ,	−295	−300	= 0
Convex Combination					1	1	, . . . ,	1	1	≤ 1

shadow price information. However, because it requires an extra constraint for each step on the supply schedule, it is more expensive computationally.

When a stepped supply function is specified *ex ante* rather than arising as an approximation, then of course there is no inconsistency problem between the dual and market wages, providing that L does not correspond to a step boundary point. In the latter event, the dual wage is degenerate but then so also is the market wage.

Not all stepped functions represent labor supply, or average cost schedules. If different types of labor can be discriminated against in the market, then the step function becomes a marginal cost schedule, and the area under it measures the total wage bill. This kind of formulation is frequently encountered in farm level models, because farm family labor is often presumed to be available at a zero, or positive, fixed reservation wage, while additional labor is provided for hire at a higher wage. Such a specification corresponds to a two-step marginal cost schedule, and the discriminating behavior arises because family labor is assumed to receive its reservation wage, even when the hired workers are paid a higher market wage. In contrast, an average cost step function assumes all employed labor receives the same market wage.

Models of this kind usually are solved using a formulation like (10) through (13), but now $\sum_k w_k L_k$ is to be interpreted as the total wage bill for family and hired labor. Although it is rarely recognized (Kutcher, p. 22–26 is an exception), the solution so obtained corresponds to a discriminating monopsonist, and the shadow wage will be greater than the average wage for the two sources of labor whenever hired labor is used. The situation is illustrated in figure 3, where it is assumed that up to 100 units of family labor are available at a reservation wage of 1.0, and additional day labor can be hired at a wage of 2.0 per unit. The market solution for the discriminating monopsonist uses 150 units of labor at a shadow wage of 2.0, but because family workers are only paid 1.0 per unit of labor, then the average wage paid is only w_1. The monopsonistic profits are $(2.0 - w_1)$ 150.

Table 2. Model Solutions to Example Problem

Variable Name	Competitive Solution	Monopsonistic Solution
COMP	1,032.66	1,030.0
MONP	842.81	880.0
Shadow wage	2.2	3.575
Market wage	2.188	2.0
Land value	8.4	5.65
X_1	25.0	—
X_2	—	—
X_3	60.0	80.0
L	225.0	200.0

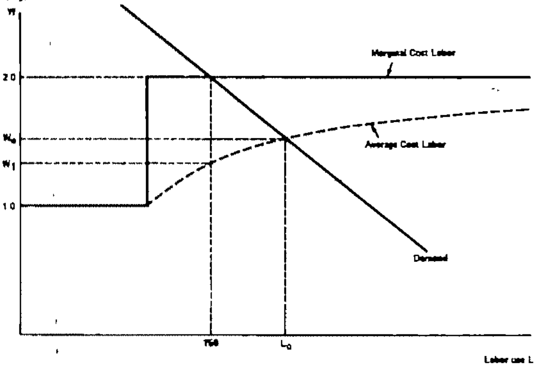


Figure 3. Labor supply for a discriminating monopsonist

Because most family labor is not paid a cash wage, and because monopsonistic profits accrue to the family anyway, this behavioral specification is not inappropriate. In any event, a competitive market would not permit of discrimination between labor sources, so that a solution like L_0 at wage w_0 in figure 3 could never be realized. In the absence of discrimination, then, the same step function would have to be interpreted as an average cost function. The model and solution would remain identical to the discriminating monopsonist, but the interpretation would be different. In the monopsonist case, family workers would be exploited, but they would retain the monopsonistic profits; while in the competitive case they would receive the same total payment, but directly through the wage rate.

Summary and Conclusions

This paper has provided a method for formulating linear programming models in which one or more factors have upward sloping supply schedules, and the prices of these factors are to be endogenously determined at their competitive market equilibrium values. The method for achieving this result is based on Duloy and Norton's (1975) treatment of competitive equilibria in product markets. In their case the product demand schedules are given exogenously, while the supply schedules are portrayed implicitly by production-decision models. In the present problem, the factor supply schedules are given exogenously, while the demand schedules are endogenous to the model. The algebra and linear programming approximations are similar for the two problems.

[Received July 1978; revision accepted November 1978.]

References

Duloy, J. H., and R. D. Norton. "CHAC, A Programming Model of Mexican Agriculture." *Multi-Level Planning: Case Studies in Mexico,* eds. L. Goreux and A. Manne, pp. 291–337. Amsterdam: North-Holland Publishing Co., 1973.

———. "Prices and Incomes in Linear Programming Models." *Amer. J. Agr. Econ.* 57(1975):591–600.

Duloy, J. H., and P. B. R. Hazell. "Substitution and Nonlinearities in Planning Models." *Economy-Wide Models and Development Planning,* eds. C. Blitzer, P. Clark, and L. Taylor. London: Oxford University Press, 1975.

Hazell, P. B. R. "A Model of the Padi Farm Sector in the Muda Economy," Mimeographed. Washington, D.C.: Development Research Center, World Bank, forthcoming.

Hazell, P. B. R., and P. L. Scandizzo. "Competitive Demand Structures under Risk in Agricultural Linear Programming Models." *Amer. J. Agr. Econ.* 56(1974):235–44.

———. "Farmers' Expectations, Risk Aversion, and Market Equilibrium under Risk." *Amer. J. Agr. Econ.* 59(1977):204–09.

Kutcher, G. P. "Agricultural Planning at the Regional Level: A Programming Model of Mexico's Pacific Northwest." Ph.D. thesis, University of Maryland, 1972.

Kutcher, G. P., and P. L. Scandizzo. *The Agricultural Economy of Northeast Brazil.* Washington, D.C.: Development Research Center, World Bank, forthcoming.

Samuelson, P. A. "Spatial Price Equilibrium and Linear Programming." *Amer. Econ. Rev.* 42(1952):283–303.

Takayama, T., and G. G. Judge. "Spatial Equilibrium and Quadratic Programming." *J. Farm Econ.* 46(1964): 67–93.

———. *Spatial and Temporal Price and Allocation Models.* Amsterdam: North-Holland Publishing Co., 1971.

A Semi-Strong Form Evaluation of the Efficiency of the Hog Futures Market

Raymond M. Leuthold and Peter A. Hartmann

Forward pricing is a primary role of livestock futures markets. A semi-strong form test of efficiency examines whether or not the prices in a market reflect all publicly available information. An econometric forecasting model is constructed to serve as a norm against which to test futures market forward-pricing abilities. Utilizing alternative methods of evaluation, results demonstrate that the live-hog futures market cannot be relied upon to reflect accurately and consistently subsequent cash prices; hence, it is inefficient.

Key words: forward pricing, futures markets, hogs, market efficiency, semi-strong form test.

Since the introduction and successful trading in the futures market of contracts for such commodities as livestock, foreign currencies, and financial instruments, analysis of the forward-pricing efficiency or accuracy of futures contracts has expanded. Inventory guidance is not as important for these commodities as for grains, hence rational price formation becomes a principal economic role for the market because futures prices can provide guidance for decision making and resource allocation. Surveys reveal very few agricultural producers hedge, but reasonable numbers of them follow futures prices (Helmuth). Rigorous modeling efforts have ascertained that potato, onion, and hog producers utilize futures prices as expected prices when making production decisions (Gray, Peck, Miller). Gardner implies soybean producers also use futures prices as expected prices. If producers are in fact using futures prices as expected output prices when allocating resources, an assessment of the "quality" of the prices is important. Miller concluded his dissertation on hogs by saying that "research is need(ed) to determine the quality of the expected prices offered by the live hog futures market. This issue has important implications for the question of whether live hog futures trading has made more efficient the resource allocation in the pork sector" (pp. 153–4).

Several agricultural economists have investigated the accuracy of futures prices as forecasts of subsequent cash prices (Tomek and Gray, Kofi, Leuthold 1974, 1975, Campbell).[1] In these studies either the final cash price was regressed on some futures price j months prior to maturity, testing if the intercept equals zero and the slope equals one, or they employed mean-squared error techniques. The evidence from these studies is mixed, with grain futures prices generally being "good" forecasters of harvest-time prices, but livestock, especially cattle, biased estimates of subsequent spot prices.[2] However, these studies lack a norm in which to compare performance results. One cannot ascertain from the statistical techniques employed if the forecast "error" between the futures price and a subsequent cash price is due to uncertainty and lack of information, or to imperfect markets and poor speculation.

The underlying aspect for determining if a market is performing efficiently is whether the market utilizes all available information. "A

Raymond M. Leuthold is an associate professor in the Department of Agricultural Economics, University of Illinois; Peter A. Hartmann is an assistant professor in the College of Applied Sciences, Lincoln University, Missouri.

The authors acknowledge stimulating and helpful comments from Bruce Dixon and two anonymous reviewers.

[1] Some researchers object to considering futures prices as forecasts, which they technically are not. Futures prices are interpreted as expectations of subsequent spot prices (see later discussion), and in the literature these expectations have become termed as forecasts. Hence, the term forecasts is used rather loosely. Discussion later in this paper differentiates forecasts from rational price formation.

[2] Using yet different approaches, Telser and Rockwell have found, respectively, futures prices as a "market expectation" or "unbiased estimate" of the subsequent spot price. A futures price is an unbiased estimate only in the case of an efficient market.

market in which prices always 'fully reflect' available information is called 'efficient' " (Fama, p. 383). Fama classified three different types of tests concerning the efficiency of markets as "weak," "semi-strong," and "strong" form. Weak-form tests rely only on a historical set of prices and often reduce to tests on the randomness of prices. Considerable empirical work on futures prices utilizing this test format exists, with one of the more recent investigations being by Cargill and Rausser. By design, these tests do not determine if all economic information is being reflected in the market. They determine only if the market correctly uses past prices in forming expectations, and thereby is efficient. The most recent evidence tends to reject the random walk hypothesis for commodity futures prices.

If prices reflect all publicly available information as it is released, the market is said to be semi-strong efficient. The efficiency of the market is tested by examining whether the expectations formed reflect currently available economic information. This test is more rigorous than the weak-form test. In commodities, the only known related effort is by Elam, where the emphasis was on potential trading profits. A strong-form test examines if any particular group in the market has monopolistic access to information needed for price formation. No known test of this hypothesis in commodities exists. An example of both weak and semi-strong form tests on Treasury bills can be seen in Hamburger and Platt.

The literature examining the forward-pricing efficiency or accuracy of futures markets apparently has not explored Working's (1949) sources of market error. He wrote that the sources of market mistakes are information and judgment, and classed market inaccuracies as "necessary" and "objectionable."

An efficient market contains only necessary inaccuracy; price changes are due to new information. Any error beyond that is objectionable inaccuracy, often termed as speculative error, and likely results from bad judgment of traders or from noncompetitive market situations. Working (1949) implies that if futures price changes are predictable, objectionable inaccuracies must exist.If the changes are unpredictable, objectionable error is absent. Relating this to Fama's terminology, the existence of objectionable inaccuracies means the market is not utilizing all the available information, hence it is not efficient. A semi-strong form test of market efficiency which examines predictability and comparative forward-pricing accuracy can determine if futures prices, while acting as expected prices, reflect all available information.

In what follows, we conduct a semi-strong form test of the efficiency of the live-hog futures market. An econometric model designed to forecast hog prices reflecting available public information is developed to act as the norm against which futures prices can be compared. Using alternative methods of evaluation, we find that on occasion the econometric model provides more accurate forecasts of subsequent prices than does the futures market, implying that objectionable inaccuracies exist in the futures market. This means that the live-hog futures market is not performing efficiently, presumably because of the market's inability to reflect fully all information.

The Model

The pure expectations hypothesis states that the current-period's futures price for a contract maturing in time $t + j$ is the current expectation of the subsequent spot price in $t + j$. Under the assumptions of an efficient-market model, that investors use all available information in forming expectations, and that information generates randomly (Working, 1958), then changes in expectations from one time period to the next, and hence changes in futures prices, are random (see Hamburger and Platt). That is, the expectations hypothesis and efficient-market model imply that the difference between the futures price in t and the spot price that evolves at $t + j$ is a random number, representing the receipt of new information. However, it is an empirical question whether the above model holds or not, and in this paper, we test this concept for the live-hog futures market in a semi-strong context.

Econometric model

The econometric forecasting model, used here to act as a performance norm, is a recursive, two-equation demand-supply model using monthly data. The underlying assumptions of the model closely follow that of the well-known cobweb model. Its purpose is strictly to forecast, first, hog slaughter and, second, cash-hog prices. By design, the forecasting

model is kept simple because, if a simple model shows the market to be inefficient, further elaboration becomes unnecessary to test the efficient-market hypothesis.[3] The statistical model is stated as follows:

Supply:

$$HS_t = \alpha_1 + \alpha_2 SF_{t-6} + \alpha_3 H - C_{t-24} + \sum_{k=1}^{11} \alpha_k DV_k + \sum_{j=1}^{3} \alpha_j SDV_j + \epsilon_{1t},$$

Demand:

$$PH_t = \beta_1 + \beta_2 HS_t + \beta_3 I_t + \sum_{k=1}^{11} \beta_k DV_k + \epsilon_{2t},$$

where HS is hog slaughter, U.S., 1000 head; SF is sow farrowings, quarterly, 1000 head, ten states; H-C, hog-corn price ratio, Omaha; PH, average price of barrows and gilts, eight markets, dollars per hundredweight (reflecting seven markets beginning in 1970 due to the closing of the Chicago market); I, personal disposable income, U.S., in billion dollars; DV_k, eleven-monthly dummy variables to shift the intercept, February through December; SDV_j, three-slope dummy variables for sow farrowings for September, October, and November; and ϵ_i, error terms.

The model consists first of a supply equation where the supply of slaughter hogs this month is hypothesized to be a function of sow farrowings six months previously, the hog-corn price ratio lagged twenty-four months, and a set of monthly dummy variables. It is widely accepted that until very recently the hog cycle has been four years in length, giving a two-year lag between the hog-corn price ratio and slaughter hogs. Essentially, the decision flow proceeds from the price ratio to sow farrowings to slaughter hogs. However, this model utilizes monthly data, and sow-farrowing data are quarterly, so sow farrowings are included in the supply equation lagged six months, the normal feeding time, rather than treated in a separate equation.

A set of eleven-monthly dummy intercept shifter variables are included to reflect the seasonality of hog slaughter. Three slope dummy variables are introduced for September, October, and November to reflect different farrowing conditions in the fall months. This gives the model a jackknife characteristic.

The demand equation, standard for recursive cobweb models, hypothesizes the price of cash hogs as a function of hog slaughter, income, and a set of monthly dummy intercept shifters. The quantity demanded of hogs is assumed equal to the number slaughtered, which in this equation is predetermined. The dummy variables reflect seasonality of price. Economic theory and logic suggests that monthly cold-storage holdings and cattle slaughter ought to be in the demand equation also. However, since this model forecasts prices three to eight months ahead, separate forecasts for each of those variables would be necessary. Development of such forecasting equations and concern with inventory are beyond the scope of this paper.

Prices and incomes are not deflated as our goal is to evaluate the performance of actual price-level forecasts. Each equation is assumed to be independent and the error terms uncorrelated so that ordinary least squares can be used as the estimating technique. Hence, once hog slaughter is known it can be inserted into the demand equation to determine price, the adjusting demand mechanism.

The monthly data for estimation were collected from standard U.S. Department of Agriculture public sources. Each equation was estimated for 1964–70, and then updated and reestimated annually through 1964–76. This produces seven sets of regression results.[4]

The Results

The appendix table presents the results for the 1964–70 and 1964–76 estimations for both equations. In the supply equation sow-farrowing and hog-corn price ratio coefficients are of expected sign and usually significant. Coefficients for the hog-corn price ratio are not significant in three instances, suggesting confirmation of the changing lag structure for hogs as suggested by Meilke's results. Enough

[3] Cobweb models often implicitly incorporate producer expectations of subsequent prices within the economic system. Expectations are rational if they fully incorporate all the available information contained in a specific set. A rational agent draws on an information set larger than historical prices, and expectations are rational if they depend upon the same things that economic theory suggests determines the variable. Thus, hog producers are assumed to generate expectations similar to that indicated by the model and hence are rational.

[4] Under the assumptions of our model, that the unknown β is a constant population parameter, to test the optimality of our updating procedure with a Kalman filter estimate would yield estimates similar to ordinary least squares. The sequential OLS estimates are identical to Kalman estimates. Hence, the updating procedures are in that sense optimal.

coefficients of dummy variable shifters are significant to indicate seasonal slaughter patterns. The R^2s are reasonably high for this model and autocorrelation is not present.

The results of the demand equation also fit well with theoretical expectations as all of the hog slaughter and income coefficients are significant and of expected sign. Coefficients for the dummy variables vary in regard to magnitude, sign, and level of significance. The fit of the equation improves as more data are added, but autocorrelation increases. Information about serial correlation of the error terms is not incorporated into the forecasts.

Market-Performance Evaluation

To evaluate the forward-pricing ability of the live-hog futures market in a semi-strong form context, the forecasts of the above model provide the norm for comparison. Since the hog-corn price ratio is lagged twenty-four months, once sow farrowings are known, values of the independent variables can be inserted into the supply equation to generate hog slaughter. This forecasted slaughter value along with other independent variables can be inserted into a demand equation to generate a predicted price.

When the quarterly sow farrowing numbers become known, and given the biological lag in pork production, price predictions can be made three, four, and five months in advance. Similarly, quarterly sow farrowing intentions can be inserted into the supply equation to generate forecasts of hog slaughter and price six, seven, and eight months in advance. Results from both forecasts will be evaluated below.

The only remaining exogenous variable which is not known in advance is income. To forecast income we chose the simple trend model of regressing current income on income lagged nine months. Using the same data periods and updating procedure for estimation as noted above for the econometric model, lagged values of income are combined with the regression results to generate forecasts for income. These forecasts are inserted into the appropriate demand equation. Tests were made of other trend models with alternative lag structures, but the improvements in forecasting abilities over the nine-month lagged model were minimal and thus were eliminated from further consideration.

Finally, the hog futures prices, measured as monthly averages of daily closes, are interpreted as expectations of future spot prices or as forecasts. We can now compare the two alternative means of forecasting future cash-hog prices, the futures price versus the forecasting model. From this it can be inferred if the futures market appears to be using the information available and conforming to the expectations hypothesis.

Evaluation Techniques

Two dissimilar evaluation techniques, a singular-statistical measure and a composite model, are used to compare the forecasting models. The singular-statistical measure is the root mean squared error (*RMSE*). If P represents the predicted value and A the actual value, computation is

$$RMSE = \left[\sum_n (P - A)^2/n \right]^{\frac{1}{2}}.$$

This measure is well accepted and used frequently in forecast evaluation. It can be viewed as a quadratic loss function, and offers a good approximation of the size of the absolute (unsigned) errors. Through the squaring process, large errors carry more weight than small errors.

The composite prediction evaluation follows from a procedure established by Nelson. Predictions from the futures market and the econometric model are essentially conditional expectations of subsequent cash prices as implied by the structure of the models and the sets of information available. If these two predictors are combined, and they utilize the available information with equal efficiency, then they should contribute equally to the accuracy of the composite prediction. If one explanatory variable contributes more to the variation of the dependent variable than the other explanatory variable, the former can be said to be from the more efficient price-discovery model or market. Assuming that the futures market and econometric model are individually unbiased predictors of the subsequent cash price, then the following composite prediction model can be specified:

$$PH_t = \beta({}_{t-i}FP)_t + (1 - \beta)({}_{t-i}PPH)_t + \epsilon_t,$$

where PH is the realized cash price of hogs at time t as defined above, $({}_{t-i}FP)_t$ is the futures price for t observed at time $t - i$ and $({}_{t-i}PPH)_t$ is the predicted cash price for t made at time

$t - i$ and generated from our above econometric model. The assumption about unbiased predictors simplifies, but is not critical to, our analysis. Theoretically, if both forecasts are equally efficient, β should equal 0.5. The coefficients reflect the weights of individual predictors and their marginal contribution to the composite predictor. The composite model is estimated by ordinary least squares, with the β restricted to lie between zero and one.

Evaluation of Results

Interpretation of the futures price being an estimate of subsequent spot prices applies only to the delivery months and not to nondelivery months. Hence, we test the two forecasts against the cash price only during the months of contract maturity, which are February, April, June, July, August, October, and December. For academic interests we also tested the models for all twelve months of the year and found no significant difference in results from those presented. The procedure followed is to compare the econometric forecast i months forward with a corresponding futures price i months prior to delivery.

Table 1 gives for annual forecast periods and the combined seven-year period the *RMSE* and composite regression weights when actual sow farrowings are used in the supply equation. The seven-year period results on the bottom line of the table show the *RMSE* for the futures market being smaller than the econometric model, and the futures market having a larger composite weight. These results would indicate the futures market is the more efficient predictor.

Table 1. Summary Measures of Forecasting Accuracy When Using Actual Sow Farrowings

	RMSE		Composite Regression Weights[b]	
Time Period[a]	*FP*	*PPH*	*FP*	*PPH*
1971(4)–72(2)	2.18	2.75	.41 (2.19)	.51 (3.01)
1972(4)–73(2)	2.95	3.35	.45 (3.10)	.70 (5.05)
1973(4)–74(2)	9.48	15.14	.64 (2.84)	.45 (1.38)
1974(4)–75(2)	7.86	3.17	.13 (.80)	.80 (4.65)
1975(4)–76(2)	10.94	5.90	.001 (.004)	1.00 (3.64)
1976(4)–77(2)	5.63	10.09	.52 (2.03)	.42 (1.99)
1977(4)–78(2)	7.09	5.07	.71 (3.36)	.35 (2.05)
1971(4)–78(2)	7.30	7.67	.57 (6.56)	.44 (5.50)

Note: *FP* is futures price; *PPH* is predicted cash price from the econometric model.

[a] The number in parentheses following the year indicates the month of the year.

[b] The number in parentheses below the coefficient is the t-ratio.

However, examination of the results year-by-year casts doubts on that conclusion. The econometric model has a smaller *RMSE* in three of the seven individual years, and it has the larger composite weight in four of the seven years. (Because of the potential multicollinearity problems, the t-test may be distorted, but, other things equal, the larger weights always have higher t-ratios.) Hence, when disaggregating the evaluative measures, the econometric model, by both measures, demonstrates periods of being the more efficient predictor. During the highly volatile period of 1974–75, both measures indicate the econometric model as the more efficient.

The evaluation measures demonstrate quite similar results when sow-farrowing intentions are used in the supply equation. (The statistical results are available from the authors.) Forecasts in this case are for the three months further out than when actual sow farrowings are used. Over the full seven years, both forecasting techniques have a *RMSE* equal to 8.9, while the futures market has a larger composite weight. The year-by-year results conform fairly closely to those just noted above; namely, that the econometric model on occasion provides more accurate estimates of subsequent spot prices than the futures market, even when forecasting as far as six to eight months forward.

Three evaluative tests were performed to validate whether in fact the econometric model itself uses information to generate improved forecasts. The model was tested year-by-year against a naive model which used last-month's cash price as the predictor of the subsequent cash price. Using *RMSE* as the evaluative technique, the naive model performed slightly better than the econometric model, while the econometric model performed slightly better under the composite prediction evaluator. However, when comparing which model indicates more accurately the correct direction of future price changes, the econometric model did substantially better. Hence, the econometric model does provide modest improved forecast information. Fur-

thermore, to rely solely upon a naive or time-series model instead of an econometric model as a performance norm would reduce our tests of the futures market to the weak-form type, contrary to the goal of conducting a semi-strong form test of market efficiency. Note throughout this analysis that the composite predictor credits the econometric model as being relatively more accurate than does *RMSE*, the standard measure in many earlier market tests.

Finally, using the econometric model to indicate the direction of futures market price changes, and utilizing the naive trading strategy of buy-and-hold if the predicted price exceeds the futures price (if opposite, sell-and-hold), substantial trading profits could have been generated between 1971 and 1978 in the hog futures market. These profits were much larger than what would be expected in an efficient market and indicate that changes in futures prices can be predicted by our econometric model. Thus, objectionable inaccuracies are present.

Implications

The semi-strong form test of marketing efficiency examines if the market employs all publicly available information in forming expectations about future spot prices. This test establishes a performance norm for comparing alternative forecasts, thereby determining if objectionable inaccuracies exist. Previously cited tests were unable to distinguish whether forward-pricing errors were due to information or judgment.

The live-hog futures market has not consistently utilized all the available market information. It appears to react slowly. The price changes in the futures market have at times been predictable, indicating the presence of objectionable inaccuracy. Hence, the futures prices for hogs are not reliable estimates of subsequent cash prices. These results hold both when using actual sow farrowings and farrowing intentions.

One institutional rule that could be blamed for this inefficiency is the daily limit in price moves which prevents the market from adjusting fully within one day to new information. Because we used monthly observations, this rule seems unlikely to be the cause for forward-pricing inefficiency. The more likely cause is poor quality speculation. This can come from inexperienced and unknowledgeable traders, poorly specified forecasting models, and/or the lack of available trading capital to take advantage of the errors.

Research cited above demonstrated that producers utilize futures prices in making production and marketing decisions. This reopens the issue that a futures market cannot act as a forecasting agency and as a medium for rational price formation (Gray, pp. 323–28), which relates to our conclusions. A good price forecast from the futures market could elicit a response (in the cobweb context) that would defeat the forecast. But with the sow-farrowing and farrowing intentions reports, producer production decisions have been made and are being reported. With this information on supply response known, futures prices should then be reflecting expected subsequent spot prices. The potential sources of inaccuracies from that point of time, such as farrowing sampling errors, production uncertainty, demand response shifts, or altering market weights and rates of gain, cannot in our judgment fully account for the magnitude of the futures market errors noted.

Whether these errors cause resources to be misallocated from production decisions cannot be ascertained specifically from this analysis due to the time horizon being shorter than the biological lag. Related research questions suggested for examination are the extent to which expectations affect cash and futures prices simultaneously, and the direction of causality between cash and futures prices and their relative impacts. However, using poor-quality futures prices in marketing- and feeding-rate decisions may cause bad timing for producers, potentially creating financial losses. Reliance by producers on inaccurate futures prices as expected prices may cause them to lose confidence in the market and ignore its potential in risk management. The relationship between trader commitments and forward-pricing accuracy needs investigation.

How can the quality or accuracy of hog futures prices as expected prices be improved? Very few people foresaw the volatile prices of the 1970s, but close examination of the data for hogs indicates the warning signs were present. Certainly, more or better informed traders could improve the forward-pricing accuracy of the futures market. One can observe from this study that few economic variables need to be examined for effective trading decisions. Because few producers ac-

tually use the market, educational programs designed to inform producers of the market's benefits might encourage a well-informed group of traders into the market. A reason for poor performance may be the lack of a sufficient proportion of producers and firms forward pricing. Active trading by commercial firms may aid in rational price formation. If lack of financial capital causes the market to react slowly to information, either reducing margin requirements or contract size may encourage additional traders to the market, thereby improving forward-pricing efficiency.

Finally, further research on market performance may find this technique applicable to other commodities. Subsequent models might identify moving-average and autoregressive components of the time series within the econometric forecasting scheme. Such expansions and improvements will gradually increase the rigor of testing the efficiency of a market or the expectations hypothesis in a semi-strong form context.

Summary

Using a semi-strong form test, we have found that on occasion the live-hog futures market has not performed efficiently. Using an econometric forecasting model as a performance norm, the futures market by comparison has not at all times fully reflected the available information. This has allowed us to observe the presence of objectionable inaccuracies. The hog futures prices cannot consistently be relied upon to reflect accurately subsequent spot prices, and thereby the market is not considered efficient.

[*Received July 1978; revision accepted February 1979.*]

References

Cargill, T. F., and G. C. Rausser. "Temporal Price Behavior in Commodity Futures Markets." *J. Finance* 30(1975):1043–53.

Campbell, G. R. "Futures Markets and Intertemporal Price Relations: Further Evidence From the Live Hog Futures Market." Unpublished paper, University of Wisconsin, 1978.

Elam, E. W. "A Strong Form Test of the Efficient Market Model Applied to the U.S. Hog Futures Market." Ph.D. thesis, University of Illinois, 1978.

Fama, E. F. "Efficient Capital Markets: A Review of Theory and Empirical Work." *J. Finance* 25(1970):383–417.

Gardner, B. L. "Futures Prices in Supply Analysis." *Amer. J. Agr. Econ.* 58(1976):81–84.

Gray, R. W. "The Futures Market for Maine Potatoes: An Appraisal." *Food Res. Inst. Stud.* 11(1972):313–41.

Hamburger, M. J., and E. N. Platt. "The Expectations Hypothesis and the Efficiency of the Treasury Bill Market." *Rev. Econ. and Statist.* 57(1975):190–99.

Helmuth, J. W. "Grain Pricing." CFTC Econ. Bull. 1, Sept. 1977.

Kofi, T. A. "A Framework for Comparing the Efficiency of Futures Markets." *Amer. J. Agr. Econ.* 55(1973):584–94.

Leuthold, R. M. "Evaluating the Price Performance of the Live Beef Cattle Futures Contract." *Ill. Agr. Econ.* 15(1975):21–25.

———. "The Price Performance on the Futures Market of a Nonstorable Commodity: Live Beef Cattle." *Amer. J. Agr. Econ.* 56(1974):271–79.

Meilke, K. D. "Another Look at the Hog-Corn Ratio." *Amer. J. Agr. Econ.* 59(1977):216–19.

Miller, S. E. "Live Hog Futures Prices as Expected Prices in the Empirical Modeling of the Pork Sector." Ph.D. thesis, Virginia Polytechnic Institute and State University, 1977.

Nelson, C. R. *Applied Time Series Analysis*. San Francisco: Holden Day, 1973.

Peck, A. E. "Futures Markets, Supply Response, and Price Stability." Ph.D. thesis, Stanford University, 1973.

Rockwell, C. S. "Normal Backwardation, Forecasting, and the Returns to Commodity Futures Traders." *Food Res. Inst. Stud.* Supplement to 8(1967):107–30.

Telser, L. G. "The Supply of Speculative Services in Wheat, Corn and Soybeans." *Food Res. Inst. Stud.* Supplement to 8(1967):131–76.

Tomek, W. G., and R. W. Gray. "Temporal Relationships among Prices on Commodity Futures Markets: Their Allocative and Stabilizing Roles." *Amer. J. Agr. Econ.* 52(1970):372–80.

Working, H. "A Theory of Anticipatory Prices." *Amer. Econ. Rev.* 48(1958):188–99.

———. "The Investigation of Economic Expectations." *Amer. Econ. Rev.* 39(1949):150–66.

Appendix

Selected Regression Results

	Supply Model		Demand Model	
	1964–70	1964–76	1964–70	1964–76
Constant	−1002.85	−409.21	45.40[a]	53.55[a]
	(−1.18)	(−0.76)	(12.73)	(12.20)
Sow farrowings	3.50[a]	3.25[a]		
	(8.54)	(13.55)		
Hog-corn ratio	17.73	13.13		
	(1.04)	(1.29)		
Hog slaughter			−.0057[a]	−.0073[a]
			(−9.60)	(−14.18)
Income			.026[a]	.030[a]
			(6.66)	(20.32)
February	−654.01[a]	−771.08[a]	−3.34[a]	−4.81[a]
	(−3.27)	(−4.30)	(−2.59)	(−2.81)
March	399.65	269.59	0.18	1.17
	(1.99)	(1.51)	(0.14)	(0.70)
April	216.10	16.22	−2.15	−2.02
	(1.08)	(0.09)	(−1.75)	(−1.21)
May	−369.00	−402.11[a]	−3.98[a]	−3.98[a]
	(−1.84)	(−2.24)	(−3.11)	(−2.37)
June	512.68	559.11[a]	−5.70[a]	−5.31[a]
	(1.84)	(2.73)	(−4.08)	(−3.10)
July	418.43	94.02	−5.55[a]	−6.32[a]
	(1.47)	(0.45)	(−3.89)	(−3.55)
August	996.45[a]	736.88[a]	−3.26[a]	−1.55
	(3.50)	(3.57)	(−2.52)	(−0.91)
September	5383.73	2670.99[a]	−0.85	−0.73
	(1.76)	(2.25)	(−0.69)	(−0.43)
October	3906.12	2670.85[a]	1.37	1.95
	(1.27)	(2.24)	(1.05)	(1.16)
November	−2804.16	2408.41[a]	−2.45	−1.65
	(−0.19)	(2.02)	(−1.98)	(−0.99)
December	160.38	63.10	−0.86	−1.26
	(0.78)	(0.35)	(−0.68)	(−0.75)
September slope	−2.75[a]	−1.83[a]		
	(−2.83)	(−4.37)		
October slope	−2.10[a]	−1.63[a]		
	(−2.15)	(−3.90)		
November slope	−0.21	−1.63[a]		
	(−0.22)	(−3.89)		
R^2	.88	.79	.74	.89
Durbin-Watson	2.07	1.66	1.61	1.14

Note: The t-ratio is in parenthesis below the coefficient.
[a] Coefficient is significantly different from zero at the 95% confidence level.

Risk Preferences and Flood Insurance

E. D. Attanasi and M. R. Karlinger

A detailed theoretical model characterizing the individual's decision to purchase flood insurance is specified and the magnitude of the risk parameter is estimated using data based on transactions of flood insurance purchases. Empirical results for several samples of this subset of the general population indicated that consumers exhibited a relatively uniform degree of risk aversion across various localities where different hydrologic and economic conditions prevailed. While the estimates presented should not be directly extrapolated to the entire population located in a flood prone area, they provide evidence that parameters determining an individual's and/or community's willingness to pay for flood protection can be measured.

Key words: disaster insurance, floods, risk aversion.

In this paper, a model characterizing the individual's decision to purchase flood insurance is specified and empirically parameterized. The model conforms to the Von-Neumann Morgenstern expected-utility hypothesis. Data used for estimating the model parameters are based on transactions of insurance purchases and also include detailed hydrologic and economic information. Recent studies (Kunreuther, Kunreuther and Slovic) appear to suggest that potential consumers of natural disaster insurance have difficulty comprehending consequences of events which cause severe losses but which occur with relatively low frequency, resulting in behavior that is inconsistent with the Von-Neumann Morgenstern expected-utility hypothesis. Results presented here for samples of insurance purchasers located in various areas subject to different hydrologic and economic conditions indicate risk-averse behavior and parameter estimates that are somewhat similar.

The plan of the paper is as follows: in the next section, a consumer decision model is presented along with assumptions relating to the form of the flood distribution, damage function, and consumer utility function. After deriving a partial equilibrium solution to the consumer optimization problem, the data are discussed. Empirical results are presented, as well as tests for the validity of the underlying model. In the concluding section, the interpretation and implications of the findings for public policy are discussed.

Consumer Decision Model

The motivation for this analysis rests largely on the failure of previous studies to characterize adequately the consumers' decision to purchase flood insurance. Among the components of a "complete," although specialized, model are assumptions relating to the level and form of the physical damage function, the probability distribution associated with flood occurrence, and a form for the consumers' utility function. In the following discussion, specifics relating to these components are considered and integrated into a decision model which can be solved to yield the optimal coverage as a function of risk preferences, premium structure, the damage function, and parameters of the probability distribution governing the occurrence of floods. Inasmuch as an explicit form of the utility function must be specified in order to estimate the model, the analysis is limited and should be interpreted as being somewhat exploratory.

In accordance with the expected-utility theory of behavior under conditions of uncertainty (Arrow), the consumer is assumed to maximize expected utility of wealth where

E. D. Attanasi is an economist with the U.S. Geological Survey, Reston, Virginia, and M. R. Karlinger is a hydrologist with the U.S. Geological Survey in Tacoma, Washington.

The authors wish to express their appreciation to the referees for helpful comments and to the National Flood Insurors Association for the data used in this study.

properties of the utility function follow the Von-Neumann Morgenstern axioms (Mossin). The utility function is assumed to be bounded, monotone increasing, and concave, with increments to wealth. With these assumptions, it may be shown that the individual's utility function exhibits risk aversion. A utility function that conforms to these assumptions and which has been used in applied studies (Gould, Friedman) is the exponential utility function of the form

(1) $$U(Y) = 1 - \exp(-\alpha Y),$$

where Y is final wealth and the parameter α is the Arrow-Pratt measure of absolute risk aversion (Arrow); that is, $\alpha = -U''(Y)/U'(Y)$. Because observed behavior seems to suggest that individual's utility functions should be characterized by decreasing absolute risk aversion, the use of the exponential utility function (exhibiting constant absolute risk aversion) in applied situations is regarded frequently with some disfavor (Arrow). The exponential utility function was used here because it allowed the algebraic separation of the individual's total wealth from that part of wealth subject to flood hazards, thus making it possible to use transactions data to estimate the risk-aversion parameter.

For the specification of the consumer's decision problem, the wealth function will take several forms, depending on damages. Flood insurance deductible provisions specify that damage reimbursements do not include the first \$200 or 2% of the amount of losses (whichever is greater) (Vaut). The argument of the wealth function includes: A, the value of the individual's assets not subject to loss; L, the maximum value of assets which are subject to flood losses; C, the amount of coverage; P, the premium rate; and X, (random) damages associated with a hazard event. In particular, if coverage and maximum liability are greater than \$10,000, expressions for final wealth are

(2a) $$W_0 = A + L - PC, X = 0,$$

(2b) $$W_1 = A + L - PC - X, 0 < X < 200,$$

(2c) $$W_2 = A + L - PC - 200, \quad 200 < X \le 10{,}000,$$

(2d) $$W_3 = A + L - PC - .02X, \quad 10{,}000 < X < C < L, \text{ and}$$

(2e) $$W_4 = A + L - PC - .02X - (X - C), \quad 10{,}000 < C \le X \le L.$$

A somewhat similar set of expressions would result if coverage were less than \$10,000. The definition of a flood used here is the instantaneous annual peak flow at a given location.

Damages generated, X, are assumed to be a monotone nondecreasing function of the particular peak discharge (McCrory, James, Jones). That is, the probability distribution associated with damages, X, is directly related to the flood discharge probability distribution through the damage function. When a particular flood is discussed, it is frequently referred to in terms of its recurrence intervals. The recurrence interval in years is defined as the reciprocal of the probability of a particular flood discharge being exceeded in any given year. Given the form and parameters of a particular probability distribution associated with floods, the discharge magnitude of a specific recurrence interval can thus be determined. For less than some minimum flood, Q_0, for example, the ten-year flood, damages are assumed to be zero (negligible). For floods greater than some catastrophic flood, Q_T, damages are set equal to the value of assets subject to flood losses. Even for small increments beyond Q_0 which result in a flood depth as small as 0.1 feet, damages average about 5% of the total value of the structure (McCrory, James, Jones). Therefore, the probability associated with the interval where W_1 holds in the wealth function is quite small. For computational convenience the respective intervals for W_1 and W_2 were combined and W_2 was employed as the relevant wealth function. This is equivalent to stating that any flood greater than Q_0 results in damages of at least \$200. In addition, in all cases 2% of maximum liability represented a small percentage of the individuals' coverage. Consequently, for computational purposes the expected utility may be written as

(3) $$\begin{aligned} E[U(Y)] &= \left(1 - \exp\{-\alpha W_0[X(Q_0)]\}\right)k_1 \\ &+ \int_{Q_a}^{Q_b} \left(1 - \exp\{\alpha W_2[X(Q)]\}\right) f(Q)\,dQ \\ &+ \int_{Q_b}^{Q_c} \left(1 - \exp\{-\alpha W_3[X(Q)]\}\right) f(Q)\,dQ \\ &+ \int_{Q_c}^{Q_T} \left(1 - \exp\{-\alpha W_4[X(Q)]\}\right) f(Q)\,dQ \end{aligned}$$

$$+ \left(1 - \exp\{-\alpha W_4[X(Q_T)]\}\right)k_2,$$

with the damages X specified according to

$$(4) \qquad X = \begin{cases} 0, \; Q \leq Q_0 \\ g(Q), \; Q_0 < Q < Q_T, \\ L, \; Q_T \leq Q \end{cases}$$

and where k_1 and k_2 are probabilities associated with flood discharges less than Q_0 and events with discharges greater than Q_T, respectively, and $f(Q)$ is the flood discharge probability density. Limits of integration Q_a, Q_b, and Q_c correspond to damage intervals defined by the relevant wealth function in equation (2). For example, Q_b and Q_c define the floods between which damages are greater than \$10,000 but less than coverage and are used in (2d). These are calculated using the inverse of the analytical form of the damage function, which was assumed to be linear between Q_0 and Q_T (fig. 1). That is $g(Q)$ has the form $a(Q - Q_0)$, where a is the slope of the damage function.[1] To complete the specification of the model, it is assumed that flood events, that is discharges, Q, follow a two-parameter log normal distribution (Aitchison and Brown).

Given a premium, the consumer is assumed to choose coverage so as to maximize expected utility. To obtain coverage the integrated form of equation (3) may be differentiated with respect to C, with the solution to the first order condition providing optimal coverage. The distribution function of damage levels is well-behaved and the utility function is concave. Because of the complexity of the resulting expectation expression, individual's optimal coverage could not be solved in closed form but was done numerically.[2] Using transactions data associated with the purchases of flood insurance, the risk parameter, α was estimated from the first order condition yielding the consumer's optimal choice of coverage. After differentiating equation (3) with respect to C, the expression, $\exp[-\alpha(A)]$, was factored from all the terms. The remaining integrand expressions containing exponential terms with the damage variable were subsequently expanded using a fourth order Maclauren's series. Estimation of α was carried out using the equation which results from the first-order condition and data for L, P, C, $g(Q)$, and $f(Q)$.

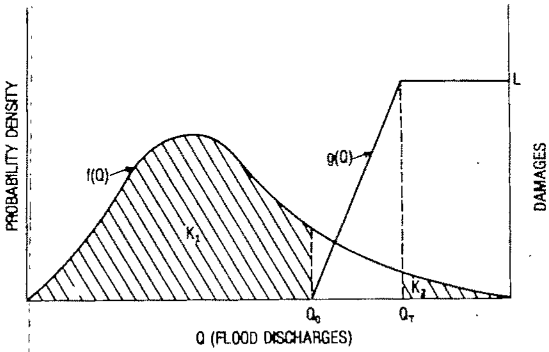


Figure 1. Damage function with weighting function

Data

The economic data are based, in part, on a sample of individual insurance contracts from four preselected towns (Clark, Cranford, Plainfield, and Elizabeth) in New Jersey. Each town was enrolled under regular provisions of the National Flood Insurance program. To be admitted on a regular basis a jurisdiction must have had a topographic and hydrologic study carried out for the development of technical information to be used in the preparation of a Flood Insurance Rate Map (National Flood Insurance Act, 1968). Once a community is admitted to the regular program, new policies are subject to actuarial rates rather than the very highly subsidized emergency program

[1] Engineering studies indicate that the relationship between economic damages and the flood discharge approximates a square root function (McCrory, James, Jones) sensitivity studies for the two alternative functional forms for an idealized situation suggested that the use of the empirically estimated linear function may have produced a slight downward bias in estimates of the risk aversion parameter.

[2] After differentiating equation (3) with respect to C (using Leibnitz's rule) and factoring out the term $\exp(-\alpha A)$, the first order condition (for the insurance purchaser with greater than \$10,000 coverage) becomes:

$$0 = (\alpha P)^{k_1} + (\alpha P)[\exp(200\alpha)]k_3 + (\alpha P - \alpha)[\exp(1.02\alpha L - \alpha C)]k_2 + \alpha P \int_{Q_b}^{Q_c} \{\exp[.02\alpha g(Q)]\}f(Q)dQ + (\alpha P - \alpha) \int_{Q_c}^{Q_T} \{\exp[1.02\alpha g(Q) - \alpha C]\}f(Q)dQ,$$

where k_3 is the probability associated with the discharge causing damages between zero and \$10,000 and the other variables are defined as above. The integral terms in the equation above were evaluated by applying Maclauren's expansion to the exponential variable terms (to the fourth order term). A similar process could be carried out to obtain the first order conditions for individuals who purchased less than \$10,000 coverage. Applying an iterative numerical procedures the value of α was estimated using the above expression.

rates. Other reasons these four towns were chosen are that only one dominant river was located in each and the localities were not subject to tidal or coastal flooding. The residences sampled were located in the AO and C flood hazard zone. Zone AO is defined to be in the one hundred-year floodplain but subject to shallow flooding (up to three feet) at the hundred-year flood. The zone C hazard area was defined as an area subject to damage beginning with the occurrence of a flood of the magnitude of the five hundred-year flood.

These zone definitions and the historic hydrologic data provided the basic information upon which the damage function was positioned. Using the hydrologic records of the individual town, estimates of the mean (μ) and standard deviation (σ) of the flood distribution were obtained. For AO zone, the flood whose estimated stage was three feet below the hundred-year flood stage was chosen to be the maximum zero damage flood, Q_0. Actual values of the hundred-year flood discharge were determined from the information provided in the topographic and hydrologic information report carried out for each town prior to entering the National Flood Insurance Program under the regular provisions. Estimated flood distribution parameters, μ and σ, were used to determine the frequency (or relatedly the cumulative probability) associated with Q_0. By definition, the exceedance probability for Q_0 in zone C is 0.002. For the AO and C zones the discharge, Q_T, which was assumed to assure maximum damage (or a catastrophic event) was chosen to be the ten thousand-year flood. In order to determine the slope of the damage function, $g(Q)$, damages were estimated for the discharge level Q_T, using engineering damage stage functions (McCrory, James, Jones).[3]

In contrast to other studies, the sample data are based on actual transactions. The information obtained from the insurance policies included a structural description of the dwelling, insurance coverage, and the premium amount. Because the exact locations of individual properties were not identified, the values of the insured buildings were estimated. Information on current market prices (less the estimated value of the typical residential lot) for houses in the same town and with similar structural characteristics was used in deriving the estimated maximum liability. The range of market prices for similar types of houses within each town was not more than 15% of the town's average value for that type of dwelling. No attempt was made to obtain data on nonpurchasers of insurance living in areas subject to the same flood risks who own buildings of the same value with similar structural characteristics. There were two reasons for this. The fact that individuals and street addresses were not identified made it difficult to design a survey to obtain information on nonpurchasers. Second, before the decision to purchase insurance can be made rationally, it is assumed that the individual has all the relevant information. Survey studies (Kunreuther) suggest that nonpurchasers are frequently ignorant not only of the potential hazard risks in the areas in which they live but also have little or no knowledge of the terms or existence of the insurance program. Consequently, the results obtained are valid only for a subset of the general population.

The insurance contract information also included data on the current premiums and the amount of coverage that the individual was carrying. As mentioned earlier, the variable, A, defined as the value of the individual's wealth was not subject to the flood hazard was eliminated after differentiation of equation (3). Given the estimated damage function, premiums, along with the procedure for adjusting premiums, coverage, and the maximum liability, individual risk aversion parameters were estimated using the procedure described in the second section.

Results and Interpretation

Estimates of the risk-aversion parameter and their sample standard deviations (table 1) across all townships are reasonably consistent. Moreover, the ratios of the coefficient estimates to their sample standard deviations for the larger samples indicate the quality of the estimates to be relatively good. While risk

[3] According to the damage table presented in McCrory, James, and Jones, stage levels greater than fifteen feet are necessary to cause maximum damage. For the AO zone market values (exclusive of land) were used as the maximum damages. Although it might be argued that floods rarely totally destroy a dwelling, it was felt that estimated market prices understated expected replacement costs of the dwelling. Alternatively, for residents of the C flood zone (a much less hazardous zone), maximum damage was set at 60% of the market value. Parameters of the flood discharge distribution (μ and σ) in cubic feet per second are for Clark, 1053 and 466; Cranford, 1053 and 466; Elizabeth, 4700 and 1689; Plainfield, 882 and 773. For the AO zones, the respective values for k_1 are .67, .67, .98, and .50 while the value for k_2 was .0001 in all cases (see fig. 1). By definition for all the C zone residents k_1 was .998 and k_2 was .0001.

Table 1. Estimated Risk Aversion Parameters

Towns	N^a	I	N	II	N	III	N	IV	N	Pooled
AO zone	4	.000355	13	.000355	9	.000347	16	.000310	42	.000336
		(.000192)		(.000164)		(.000120)		(.000131)		(.000140)
C zone	5	.000236	1	.000100		—		—	6	.000213
		(.000171)		—		—		—		(.000162)
Pooled data	9	.000289	14	.000333	9	.000347	16	.000310	48	.000319
		(.000180)		(.000186)		(.000120)		(.000131)		(.000152)

Note: Numbers in parentheses are standard deviations.
[a] N is the sample size. Towns are I, Clark; II, Cranford; III, Plainfield; and IV, Elizabeth.

parameter estimates for C zone residents were lower, this may be the result of a small sample size. The relative uniformity in the estimated levels of risk aversion is worth noting. In most cases the market value of housing for township IV was estimated to be about three-fourths the market value of similar housing in townships I and II. Income levels for township IV were also relatively lower. Uniformity in the estimates of the risk parameter across townships is consistent with constant absolute risk aversion.

In order to examine how the individual's demand, i.e., premium versus coverage, changes as the risk-aversion parameter changes, the consumer model was used to obtain reservation price as a function of coverage. The hydrologic assumptions corresponded to the case for a resident in the AO zone in township I or Clark, New Jersey, with the maximum liability set at $40,000. Results indicate that the individual's demand for insurance becomes more price inelastic and shifts to the right (for any given premium the optimal insurance coverage increases) as the risk parameter value increases. An example of the shift is shown by figure 2 for risk parameters equal to .00030 and .00035.

Conclusions

The results of this analysis have several implications. Estimated risk coefficients were all positive and different from zero. Behavior of the sampled individuals who purchased insurance was not inconsistent with the expected utility hypothesis. The uniformity in the values of the estimated risk parameters across townships may suggest a broader applicability of the estimated utility function. Estimates of the risk parameters and the results of the numerical experiments applying these estimates appear to be reasonable.

The federal flood insurance program was instituted to avoid the inefficiency of society as a whole bearing the cost of flood protection in the form of structural flood control measures (reservoirs, levees, etc.) while benefits accrue to relatively few individuals (Dacy and Kunreuther). Community participation in the regular program requires that some floodplain landuse-planning measures be instituted. Estimates of a community's willingness to pay for flood protection might enable officials to structure premiums to generate sufficient rev-

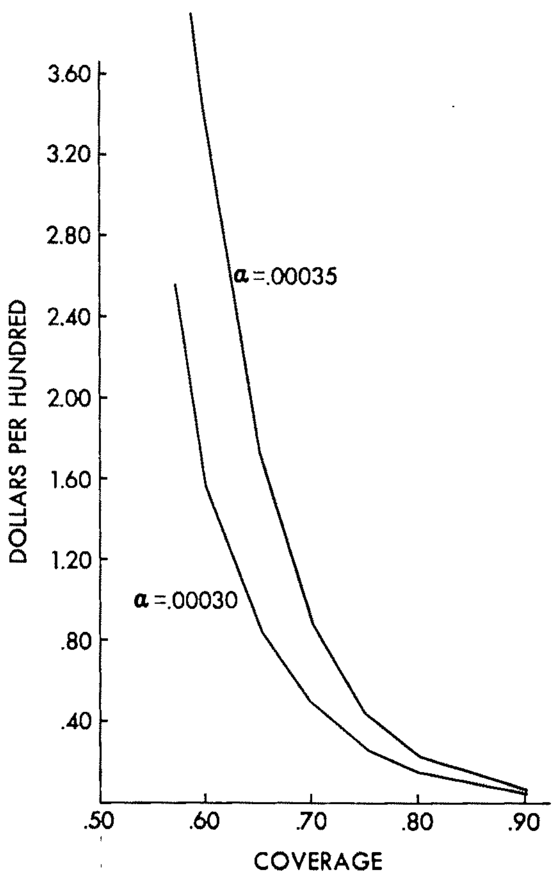


Figure 2. Price vs. coverage

enue to pay for structural flood protection measures or induce abandonment of the floodplain (if insurance is mandatory). Estimates might also be employed in the design of multipurpose (flood control, recreational, hydroelectric) water resource projects (Maass et al.).

When considering the direction of future research, these results should be placed in perspective with other studies relating to individual behavior and natural hazard events. First, although other forms of the utility function might yield different results, use of the lognormal distribution to describe flood events severely limited forms that were analytically tractable. Second, the sample used in this study was restricted to those purchasing insurance. Presumably, these individuals were relatively well-informed about the nature of the natural hazard event. Kunreuther, on the basis of the results of survey studies, has suggested that there is a positive and perhaps significant cost associated with becoming informed about the nature of the flood hazard. These explanations may in part account for the seeming inconsistencies in observed behavior with economic theories that have been reported. It appears that more needs to be known about individuals who did not purchase insurance. Perhaps the decision to purchase insurance should be modeled using a threshold approach (Kunreuther). It has also been argued that flood insurance marketing efforts have been less than vigorous. The nature of risks associated with residing in the floodplain must be communicated in a manner that can be understood by the general population. Efforts appear to be underway to remedy the problem of nonparticipation (Vaut). While the empirical estimates presented here should not be directly extrapolated to the entire population located in a flood prone area, they provide evidence that critical parameters determining the individual's demand for insurance can be measured. If greater levels of participation are brought about by efforts to inform residents of the damages of floods and through increased marketing efforts, the methodology presented and type of information used in this study provide a means for estimating a community's willingness to pay for flood protection.

[Received July 1978; revision accepted February 1979.]

References

Aitchison, J., and J. C. Brown. *The Log-Normal Distribution*. London: Cambridge University Press, 1957.

Arrow, K. *Essays in the Theory of Risk Bearing*. Chicago: Markham Publishing Co., 1971.

Dacy, D., and H. Kunreuther. *The Economics of Natural Disasters*. New York: Free Press, 1969.

Friedman, B. "Risk Aversion and the Consumer Choice of Health Insurance Option." *Rev. Econ. and Statist.* 55(1973):209–14.

Gould, J. P. "The Expected Utility Hypothesis and the Selection of Optimal Deductibles for a Given Insurance Policy." *J. Business* 42(1969):143–57.

Kunreuther, H. "Limited Knowledge and Insurance Protection." *Public Policy* 24(1976):227–61.

Kunreuther, H., and P. Slovic. "Economics, Psychology, and Protective Behavior." *Amer. Econ. Rev.* 68(1978):64–69.

Maass, A. M., M. M. Hufschmidt, R. Dorfman, H. A. Thomas, S. A. Margin, and G. M. Fair. *Design of Water Resource Systems*. Cambridge, Mass.: Harvard University Press, 1962.

McCrory, J. A., L. D. James, and D. E. Jones. "Dealing with Variable Flood Hazard." American Society of Civil Engineers Water Resources Planning and Management Div. *Proceedings*, vol. 102, no. WR2, pp. 193–208, Nov. 1976.

Mossin, J. "Aspects of Rational Insurance Purchasing." *J. Polit. Econ.* 76(1968):553–68.

Vaut, G. A. "The Economics of Flood Insurance: An Analysis of the National Flood Insurance Program." Water Resources Research Center Rep. No. 46, University of Massachusetts, 1974.

Flood Insurance or Disaster Loans: An Economic Evaluation

Michael J. Rettger and Richard N. Boisvert

Alternative federal flood disaster assistance programs are evaluated through an economic comparison of flood insurance and disaster loan programs. The distribution of costs, benefits, and program transfers, both private and public, are simulated over time and are analyzed to determine the sensitivity of program performance to specific program parameters. Empirical results demonstrate that both programs provide adequate levels of protection at approximately equivalent costs. Variations in premium and interest rate subsidies have major effects on the distribution of total costs between the public and private sectors.

Key words: disaster loans, flood insurance.

Since the 1950s, the Small Business Administration (SBA) and the Farmer's Home Administration (FmHA) have been the primary sources of federal aid to flood victims (Dacy and Kunreuther). Recent sharp criticism has been directed at these and other loan programs which, through interest rate subsidies and liberal forgiveness provisions, have contributed to increased federal relief costs for every major flood disaster since 1960 (Kunreuther). Critics argue that by shifting costs to the federal government, these programs subsidize the development of the nation's floodplains and are responsible in part for the growth in average annual flood damages from $250 million in 1950 to $1.5 billion in 1975 (U.S. Congress).

As an alternative, the federal government has established the National Flood Insurance Program (NFIP). The program provides some subsidies to the insurance rates paid on existing floodplain properties, but it is intended to operate ultimately on a sound financial basis, with the major burden of flood losses to be paid by those exposed to the hazard. The program seeks to control future flood losses by requiring communities to adopt strict regulations governing new and renovated buildings in flood hazard areas.

Research evaluating these alternative relief and insurance programs is beginning to appear. Schaake and Fiering and Friedman and Roy derived countrywide estimates of program performance, costs, and benefits from temporal simulations of a flood insurance fund, but neither study estimated similar results for alternative relief programs. Kunreuther, on the other hand, compared the impacts of flood insurance and the SBA loan program on hypothetical victims of a single major flood disaster.

The study on which this article is based involves a more comprehensive economic comparison of emergency and regular flood insurance programs and SBA-type disaster loan programs (Rettger). The distributions of costs and benefits among participating groups, both public and private, are simulated over time and are analyzed to determine the sensitivity of program performance to specific program parameters. Although the empirical results are based on a case study of the Binghamton, New York, metropolitan area, the simulation methodology could be adapted to other areas.

Flood Insurance and Loan Programs

Established in 1968, the NFIP provides federally subsidized insurance against flood losses to properties in flood hazard areas. In order to provide for both immediate and longer-term needs for insurance coverage of flood-prone

---

Michael J. Rettger is an economist with the Michigan State Insurance Department; Richard N. Boisvert is an associate professor of agricultural economics, Cornell University.

Funds for this research were provided in part by the Center for Environmental Research, Cornell University, through the Annual Allotment Project No. A-074-NY from the Office of Water Research and Technology, U.S. Department of the Interior.

communities, the NFIP is designed to operate at two levels (Flood Disaster Protection Act, P.L. 93-234). Initially, usually after the issuance of a Flood Hazard Boundary Map (FHBM), a community can qualify for the "emergency" flood insurance program by adopting and enforcing minimum land-use standards. After a flood insurance study of the community has been prepared to determine flood profiles, actuarial insurance rates, and floodplain boundaries, the community becomes qualified for the "regular" flood insurance program. To enroll a town must, within six months of qualification, adopt strict land-use regulations establishing minimum building elevation and floodproofing standards and floodway encroachment boundaries.

Emergency program insurance rates are legislatively established and apply to first-layer coverage (e.g., single-family residential coverage is limited to \$35,000 structure and \$10,000 contents coverage) on all properties constructed in a community prior to the determination of actuarial insurance rates. Actuarial rates, once specified, apply to all new construction and substantial improvements begun after the actuarial rates become effective, to all properties for which actuarial rates are less than emergency program rates, and to "additional" coverage in excess of emergency program limits.

To encourage participation by communities in the flood insurance program, the Flood Disaster Protection Act of 1973 provides that failure by a community to join the program within one year of being formally identified as flood-prone will result in the prohibition of all direct federal financial aid for purposes of acquisition or construction in identified flood hazard areas [P.L. 93-234]. Under amendments in the Housing and Community Development Act of 1977, conventional mortgage funding remains available in nonparticipating communities [P.L. 95-128].

The SBA disaster loan program also was chosen for comparative evaluation because it has been the major source of federal aid for nonagricultural flood damages since its inception in 1953 (Dacy and Kunreuther). The analysis focuses on physical-loss disaster loans, which are made available to finance repairs of damaged buildings and personal property.

Under this program, a property owner may obtain a disaster loan for an amount equal to the replacement cost of damaged property. Repayment regulations now and in the past have provided for substantial interest rate subsidies. At the time this study was made, however, such subsidies were prohibited, and interest rates were set at the U.S. Treasury cost of borrowing, plus an additional 0.25% to cover administrative costs. The length of the loan may extend up to thirty years and initial repayment may be deferred up to three years in hardship cases.

Although not under SBA control, Internal Revenue Service (IRS) regulations also affect loan program costs. Unreimbursed losses may be deducted from taxable income as casualty losses, and additional deductions may be taken for loan interest payments in calculating individual and business tax liabilities. Because these tax deductions are not allowed if losses are indemnified, they must be considered when comparing disaster loans with disaster insurance.

Evaluation Methodology

Alternative relief programs were evaluated by comparing the private and government costs of providing equivalent levels of disaster assistance to flood victims. Private costs to individuals can be measured directly by the cost of payable insurance premiums. Government costs arise when subsidies are introduced to reduce premiums paid by individuals below actuarial insurance costs. Benefits to the individual depend on levels of reimbursement for future flood losses.

Loans differ from "pure" insurance because there is no expense prior to a loss. Operation of a loan program permits the individual to shift the burden of loss to the government at the time of the disaster, and thereby to defer reassumption of the loss until repayment of the loan. A loan program does not reduce the uncertainty of experiencing a loss, but may reduce the magnitude of costs incurred for a loss which does occur.

Evaluation of the loan program centers on the cost of repayment which, discounted on the basis of annual payments, is equal to

$$(1) \qquad C^* = (LN)\left[\frac{i}{1-(1+i)^{-N}}\right]\left[\sum_{k=1}^{N}\frac{1}{(1+r)^k}\right],$$

where N is the term to maturity, i is the loan borrowing rate, r is the individual's cost of

borrowing, and LN is the amount of the loan principal equal to the amount of loss incurred (Selby). If $i = r$, the present value of repayment costs equals the loan principal. In cases of imperfect capital markets, $i < r$, the present value of loan cost is less than the original loan principal. This difference (an implicit subsidy) allows a loan to function as an alternative to flood insurance.

Given a fixed repayment principal net of forgiveness grants, the benefit of a loan program is determined by the differential between the actual loan interest rate and the individual's opportunity cost of borrowing [see equation (1)]. If the loan rate is just equal to the government's borrowing cost, this loan benefit is provided at no explicit cost to the government; rather the loan subsidy is created by the elimination of inequities in existing financial markets. If the loan rate is set below the government's cost of borrowing, however, explicit costs to the government are created. The additional rate subsidy requires that the government pay the cost differential between the borrower's annual cost at the actual loan rate (i), and the amount the borrower would have paid at the government rate, defined by (g). Discounted over the life of the loan, this government loan subsidy cost may be expressed mathematically as

$$(2) \qquad S_G = LN\left\{1 - \left[\frac{i}{1-(1+i)^{-N}}\right]\left[\sum_{k=1}^{N}\frac{1}{(1+g)^k}\right]\right\}.$$

A second subsidy involved in the loan program is the reduction in tax liabilities for casualty losses and interest payments. If the individual has an effective tax rate (t), the casualty loss element of this transfer is simply

$$(3) \qquad S_{CL} = (LN)(t),$$

where LN is the amount of unreimbursed loss, as assumed earlier. The present value of the tax transfer for loan interest payments is calculated as

$$(4) \qquad S_{IP} = (LN)(t)(i)\sum_{k=1}^{N}\left[\frac{1-(1+i)^{-N+k-1}}{1-(1+i)^{-N}}\right]\left[\frac{1}{(1+g)^k}\right],$$

where the first bracketed quantity is the proportion of the loan balance outstanding in period k and discounting is calculated at the lower borrowing rate g to assure equal evaluation of the subsidy by both the government and individuals. Combining these expressions, the total value of the tax transfer subsidy becomes

$$(5) \qquad S_T = (LN)(t)\left\{1 + (i)\sum_{k=1}^{N}\left[\frac{1-(1+i)^{-N+k-1}}{1-(1+i)^{-N}}\right]\left[\frac{1}{(1+g)^k}\right]\right\}$$

A third form of subsidy involves government forgiveness grants (F) to reduce the amount of principal subject to repayment. The availability of such grants generally varies with political concern about the magnitude and severity of disaster losses.

Overall, the cost of the loan program to the individual is determined by the loan interest rate, the individual's borrowing cost, and the individual's tax rate. As a single expression, this cost is $C' = C^* - S_T$ (Rettger and Boisvert). Similar factors determine the cost of the loan program to the government which is calculated as $S' = S_G + S_T$. If forgiveness grants were available, the basis of the loan cost calculation would be $(LN - F)$, with the change affecting both the individual and government costs of the loan program.

A straightforward evaluation of these alternative programs is difficult because flood damages vary from year to year and cannot be predicted with certainty. Therefore, empirical estimates of program costs and reimbursements are determined using a simulation model.

Empirical Model Specification

The primary study area is the City of Binghamton, New York, a community of 80,000 population at the confluence of the Chenango and Susquehanna Rivers. The city is an established commercial center which has experienced a major shift in its employment base from industrial to administrative and light manufacturing activities. The housing stock is relatively old; only 15% of all units have been constructed since 1950.

The balance of the study area is Endwell, New York, a community of about 16,000 people located on the main branch of the Susquehanna about three miles downstrean from

Binghamton. Endwell is a residential community and has experienced recent gains in population. The housing stock is somewhat newer than that of Binghamton; nearly 40% of all units have been built in the last twenty-five years (Rettger).

Floodwalls protect most of Binghamton along the Susquehanna from smaller floods, but many areas along the Chenango remain exposed to low-level inundation. Much of Endwell is also exposed to flooding, although a railroad embankment does protect part of the community from minor floods.

To evaluate the loan and insurance programs, property value data were obtained from surveys of existing residential and commercial properties conducted by the Corps of Engineers (Robillard). Each property in the study area was classified according to the size and condition of building, the value of interior furnishings, and the existence or absence of a basement. With these data and stage-damage information from the Susquehanna River Basin Commission (SRBC), it was possible to estimate damage potential based on the actual cash value of each property.

Several adjustments to these data were needed. For example, the aggregate damage estimates presented in the SRBC report had to be separated into structure and contents components; this was achieved by relating asset holdings to relative annual expenditures in each of these categories (U.S. Department of Labor). The estimates also were adjusted to current price levels by use of appropriate construction and consumer price indices (Rettger).

Flood profiles for the study area were calculated from information about floodplain topography and floodwall heights, using the HEC-II Water Surface Profile Program (Hydrologic Engineering Center). This program translates specified stream discharge levels into flood stage elevations, both within the channel and across the adjacent floodplain. It shows water elevations for an entire length of the river, as well as elevation differences for different flood levels. The information is plotted on local topographic maps to determine the boundaries of floodwaters for specific flood events. These maps, prepared for Robillard's earlier study, were used to delineate the heights of the 100- and 500-year floods along individual reaches of the Susquehanna and Chenango Rivers and to allocate the properties among three floodplain categories on the basis of each building's first floor elevation.

The diversity of flood exposure is seen in the distribution of properties among hazard areas (table 1). Within the study area there were nearly 4,700 residential structures with a total value of $234 million. About 28% of these properties were located in the 100-year floodplain, with another 27% situated outside the 100-year floodplain, but within the 500-year floodplain. This distribution varied considerably among property-value classes. Only 11% of high-valued properties, for example, were located in the 100-year floodplain, compared with 24% and 34% of the middle- and

Table 1. Distribution of Survey Properties by Hazard Areas, 1976

	100-Year Floodplain		100- to 500-Year Floodplain		Outside Floodplain	
	Number	$ Value[a]	Number	$ Value[a]	Number	$ Value[a]
Residential						
High value (above $42,000)[b]	15	1,814,900	44	4,922,470	73	8,679,780
Middle value ($24,000-$42,000)	578	37,339,510	759	48,877,315	1,107	71,062,640
Low value (below $24,000)	710	18,817,185	487	14,892,940	921	27,875,515
Total	1,303	57,971,595	1,290	68,692,725	2,101	107,617,935
Commercial						
Total	447	25,654,969	357	20,966,492	476	25,238,242

Source: Estimated from U.S. Army Corps of Engineers unpublished data (Rettger).

[a] Because a structure's contents also can be insured, the value figures reported in the table include repair and replacement costs of building contents less normal depreciation for furnishings and equipment. This explains why the average value of property in a particular property class may be higher than the value range indicated. The value of "durable" contents was estimated to range from 48% of the low value structures to 35% of the high value structures (Rettger).

[b] These value ranges are the "cash values" for the structures only (e.g., the costs of repair or replacement of structural components such as walls, flooring, and foundation).

low-valued properties, respectively. The adjacent 100- to 500-year floodplain contained approximately one-third of the high- and medium-value properties, but contained approximately one-fourth of properties in the lowest-value group.

The study area also contained 1,280 commercial properties with an aggregate value of $72 million. These properties showed somewhat greater loss exposure, with 35% located in the 100-year floodplain, and another 29% located in the 100- to 500-year flood fringe.

The property damage and hydrologic characteristics of this study area were combined with simulated flood losses to evaluate insurance and loan programs. The general operation of the simulation model, displayed in figure 1, may be divided into three distinct functions: physical damage estimation, financial impact calculation, and relocation adjustment.

In the physical damage portion of the model, simulated random flood events are specified to establish floodwater elevations for each year of a simulation flood profile.[1] Stage-damage curves for the Susquehanna Basin (SRBC) are used to translate floodwater

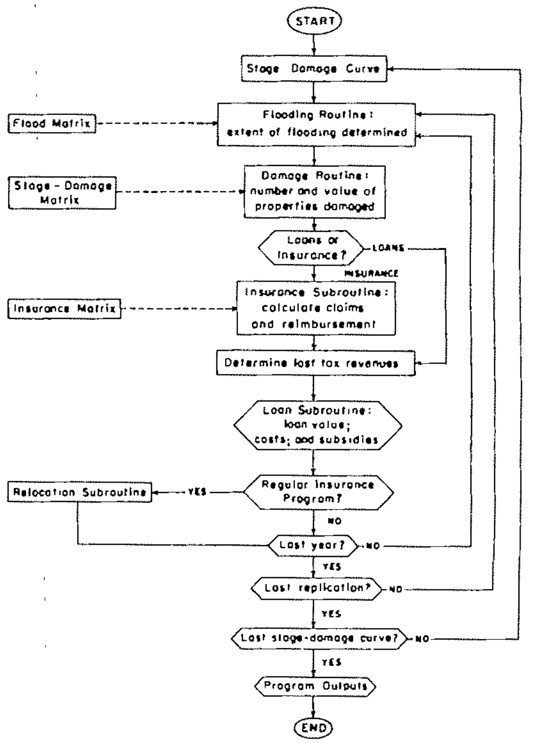


Figure 1. Flow chart of the flood relief simulator

elevations into specific damage estimates for sets of individual properties, which are grouped by property elevation and by various structural characteristics related to damage potential. Although properties are handled as groups in this and other portions of the model, parameter estimates are equal to those which would be measured if each property were evaluated individually by the simulator.

Property damage estimates initiate operation of the financial impact portion of the simulator. For simulation runs involving insurance alternatives, insurance premiums and premium subsidies are recorded, and damages are reimbursed up to coverage limits, net of deductibles. If the model specification involves a loan program, loans are granted for any damages not reimbursed by insurance (except deductibles) and loan costs and loan subsidies are calculated according to equations (1) and (2). Finally, according to equations (3) through (5), the simulator determines tax transfers based on unreimbursed losses and loan payments, and on implied income levels estimated from ratios of median income levels to median property values for various income categories (U.S. Department of Com-

[1] Each simulated flood event was selected randomly from an estimated probability distribution of peak discharges. Historic discharges from a gauging station near Binghamton were used to estimate the parameters of this Log-Pearson Type III frequency distribution:

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i;\; S = \left[\frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})^2\right]^{\frac{1}{2}};\text{ and}$$

$$G = \frac{N}{(N-1)(N-2)S^3}\sum_{i=1}^{N}(X_i - \bar{X})^3;$$

where X_i is logarithm (Base 10) of annual peak flow in cubic feet/second (cfs) in year i; and N is the number of events in the sample record. Using this information and Log $D = \bar{X} + KS$, where D is the estimated annual peak discharge and K is a deviation factor calculated on the basis of a selected exceedence probability $[P(D \geq D^*)]$ and the computed skew coefficient (G), one can define "flood potentials in terms of peak discharge and exceedence probability at locations where a systematic record of peak flow is available" (U.S. Water Resources Council, p. 9). The K values for various exceedence probabilities and skew coefficients are tabulated by the U.S. Water Resources Council (pp. 3-1–3-27).

The estimated values of the parameters for the study area are $\bar{X} = 4.697$; $S = 0.12575$; and $G = 0.27166$. Discharges for each of the simulated flood events were randomly selected according to this frequency distribution. Using these discharges and the flood profiles from Robillard, the floodstage (mean sea level) was calculated using the following polynomial function of discharge (estimated by least squares on the basis of twenty-eight years of gauge station data):

$$\text{Flood Stage} = \underset{(7.69)}{805.66} + \underset{(7.87)}{3.24\text{X}10^{-4}D} - \underset{(1.72)}{1.12\text{X}10^{-8}D^2} + \underset{(0.77)}{2.78\text{X}10^{-9}D^3};$$

$$\bar{R}^2 = 0.99; \quad (\quad) = t\text{-ratio.}$$

merce). Effective federal tax rates were assigned from data in Musgrave and Musgrave.

Under insurance program regulations, properties receiving substantial flood damages do not qualify for premium subsidies in the future. The third portion of the simulator estimates the impact of these higher insurance costs on decisions to relocate out of the floodplain, based on the present value of future insurance costs and the existing relationship of property value to household income. If the total housing costs rise above 2.5 times estimated household income, the homeowner is assumed to relocate outside the floodplain. This estimate is made only for residential properties because of difficulties involved in establishing appropriate relocation standards for commercial properties.

Analysis of Alternative Programs

Simulation results were averaged over 30 years and 25 replications for evaluation purposes. For each year, 25 individual peak discharges were selected according to the Log-Pearson Type III discharge frequency distribution. This resulted in a matrix of 750 peak discharges, only some of which were sufficiently large to result in flooding and/or flood damages. To facilitate comparison and evaluation, each of the loan and insurance alternatives was examined using this same matrix of flood events to generate physical damage estimates.

On average, 226 residential properties receive over $660,000 in flood damages each year; about 33 commercial properties receive damages amounting to over $400,000 (table 2). Over 95% of average residential losses are borne by the middle- and low-value property classes. This result is explained primarily by the fact that the majority of floodprone properties are in these classes.

Substantial year-to-year variability was present in the damage estimates, as evidenced by the tremendous range of flood damages seen in the data for selected high and low probability flood events (table 2). Total damages range from $197,000 for the 2-year flood to over $57 million for the 500-year event. The number of structures damaged range from 132 in the 2-year flood to 4,260 in the 500-year flood.

In general, the 1977 insurance coverage limits evaluated in this study for both the emergency and the regular flood insurance programs appear adequate relative to potential exposure, except in the case of the high-value residential class, where low limits for contents coverage produce low overall protection levels for both programs (table 3). This result may have been different if recent increases in coverage limits allowed by the Housing and Community Development Act of 1977 (P.L. 95-128) had been used. Despite these apparent inadequacies, however, simulation results revealed the specified amounts of insurance to be adequate to cover losses.

Data from tables 1 and 3 indicate payable insurance costs per dollar of coverage vary substantially between programs. In moving from the emergency to the regular insurance

Table 2. Flood Damages for Selected Flood Events

	2-Year Flood		100-Year Flood		500-Year Flood		Annual Averages All Events[b]	
Property Class[a]	Structures	Damages ($)	Structures	Damages ($)	Structures	Damages ($)	Structures	Damages ($)
Residential								
High value	0	0	48	285,702	100	1,890,660	3	20,481
Middle value	61	77,265	997	5,469,327	1,844	21,765,863	135	461,888
Low value	52	40,617	388	1,571,754	1,478	9,932,151	88	178,670
Subtotal	113	117,882	1,433	7,326,783	3,422	33,588,674	226	661,039 (482,762)
Commercial								
Subtotal	19	79,235	222	5,484,236	838	24,260,374	33	419,472 (331,534)
Total	132	197,117	1,655	12,811,019	4,260	57,046,312	259	1,080,511

Note: An *n*-year flood has a probability of 1/*n* of being equaled or exceeded in any year.

[a] See table 1 for property class definitions.

[b] These averages are the mean number and value of damaged properties over all 750 sample flood events used in the simulation model. The numbers in parentheses are standard deviations.

Table 3. Initial Insurance Costs and Coverage (Beginning of Simulation)

		Emergency Program		Regular Program				
Property Class	No. of Insured Properties	Payable Premiums[a] ($)	Protection Level[b] (%)	Payable Premiums ($)	Actuarial Premiums[c] ($)	Protection Level[b] (%)	Average Subsidy[d] ($)	No. of Subsidized Properties
Residential[e]								
High value	59	7,228	39	8,902	11,023	67	193	11
Middle value	1,337	154,840	66	173,415	248,204	82	172	434
Low value	1,197	80,677	82	82,169	184,488	97	171	599
Subtotal	2,593	242,745	69	264,486	443,715	86	172	1,044
Commercial								
Subtotal	804	296,940	99	218,787	1,006,211	100	2,415	326

[a] Emergency program insurance rates are $0.25 ($0.40) and $0.35 ($0.75) per $100 of residential (nonresidential) structure and contents coverage, respectively.
[b] Ratio of total coverage to total exposure. Coverage is equal to the lesser of program limits or actual property value (table 1).
[c] Actuarial insurance rates are based on the type of structure, the elevation of the first floor, and the flood hazard factor (FHF). The FHF is defined as the difference in flood elevation between a 10-year and a 100-year flood. For reaches along the river, these FHF's were calculated using the HEC-II flood profiles reported in Robillard. Once this was accomplished, actuarial rates were determined from NFIP rate tables (National Flood Insurers Association, pp. B3-B4). The difference between actuarial and payable premiums is the premium subsidy.
[d] Per subsidized property.
[e] See table 1 for property class definitions.

program, payable residential premiums increase 9%, but coverage rises by 25%; for commercial properties, payable premiums actually fall by 26% as coverage increases slightly. These changes suggest that although emergency program rates may be highly subsidized in specific instances, they are higher for many properties in the study area than the average actuarial rates. Only 40% of the residential properties qualify for a premium subsidy, which averages $172 per property; over 57% of the subsidized residential properties are in the low-value property class (table 3). The same proportion of commercial properties (40%) receives an average subsidy of $2,415 each.

The simulation model focuses on the two insurance programs and two loan program alternatives (table 4). In the "regular" insurance program, all properties are assumed to be insured to either property value or to program coverage limits (if less), at actuarial or emergency insurance rates, whichever is lower.[2] Flood damages are reimbursed first from insurance coverage, with any remaining losses (net of insurance deductibles) qualifying for twenty-year disaster loans at a 6⅝% annual interest rate. Properties with structural losses in excess of 50% of total value are assumed to need "substantial improvement" and are excluded from future insurance subsidies.

With an average claim of $2,500 per residential property, this program is able to reimburse over 99% of all allowable claims from insurance funds and over 85% of losses. The average claim cost is much higher for commercial properties ($12,000), but insurance reimbursement is still over 99% of claims and 95% of losses. Average supplemental loan requests are quite small, never exceeding 10% of property damage.

Overall, the actuarial premiums for residential properties (paid premiums plus subsidy) are below reimbursement costs (e.g., 78% of claims). Commercial payable premiums are slightly less than reimbursement costs (e.g., 97% of claims), although total actuarial premiums exceed insurance claims by 150%.[3] Thus, while the regular program provides high levels of insurance coverage at relatively low costs to program participants, these results are an initial indication that nationwide insurance rates, as set by NFIP, may not be especially accurate for specific flood-prone areas.

[2] It was beyond the scope of this research to estimate insurance program participation rates. Also, it was not possible to estimate the flood damage threshold at which a presidential disaster declaration would be issued and disaster loans would become available or the proportion of eligible property owners that would apply for the loans. Thus, 100% participation in all programs was assumed to facilitate consistent evaluation.

[3] The payable premiums reported for this model differ slightly from the insurance parameters reported in table 3 because of the impact of the "substantial improvement" provision. The change is not significant for residential properties, but in the case of commercial properties, payable premiums are 80% higher than they would have been without this provision. As a measure of sensitivity, this same program was modeled using an 80% substantial damage limit; changes in payable premiums were not significant for either commercial or residential properties (Rettger and Boisvert).

Table 4. Comparison of Average Annual Costs for Alternative Relief Programs

	Participant Cost				Government Cost						
	Paid Premiums	Loan Cost[a]	Tax Transfer[b]	Participant Cost[c]	Premium Subsidy	Loan Subsidy[d]	Tax Transfer[b]	Government Cost	Program Cost	Insurance Claims[e]	Loans for Unreimbursed Losses[e]
	$										
Residential											
Regular insurance program	265,218	3,666	978	267,906	177,976	374	978	179,328	447,234	568,133	4,127
Emergency insurance program	242,744	7,573	2,179	248,138	179,230	764	2,179	182,173	430,311	568,133	8,439
Unsubsidized loans	0	572,277	171,493	400,784	0	59,859	171,493	231,352	632,136	0	661,039
Subsidized loans[d]	0	84,478	31,326	53,152	0	573,215	31,326	604,541	657,693	0	159,720
Modified insurance program, corrected rates[f]	276,502	7,573	2,179	281,896	205,438	764	2,179	208,381	490,277		
Commercial											
Regular insurance program	392,061	1,127	927	392,261	614,169	120	927	615,216	1,007,477	402,325	1,327
Emergency insurance program	296,939	1,246	1,025	297,160	793,106	133	1,025	794,264	1,091,424	402,325	1,467
Unsubsidized loans	0	356,311	292,977	63,334	0	37,985	292,977	330,962	394,296	0	419,472
Subsidized loans	0	146,960	143,320	3,640	0	262,134	143,320	405,454	409,094	0	286,155
Modified insurance program, corrected rates[f]	89,714	1,246	1,025	89,935	237,902	133	1,025	239,060	328,995		

[a] Based on equation (1). Based on a procedure by Haveman, discount rates (r) varied among property classes. Average rates were set at 9%.
[b] Based on equation (1). Tax rates (t) are 23.6%, 20.3 and 16.3 for the high-, middle- and low-value property owners (Musgrave and Musgrave). Tax rates for commercial properties were estimated at 47%.
[c] Adjusted for out-of-pocket costs, such as deductibles which are not covered by insurance or loans.
[d] Assumes interest rate of 1%, forgiveness of first $5,000 of principal.
[e] The difference between property damages and the combined total of claims and loans is equal to insurance deductibles.
[f] The rates are corrected for differences between current rates and rates that would cover expected losses from the simulated runs (Rettger).

The emergency flood insurance program currently governs over 90% of the NFIP communities. This program differs from the regular program in that insurance rates are legislated to be uniform, regardless of exposure, and coverage limits are half of those in the regular program.

Coverage under this program remains adequate despite the lower coverage limits. Although average loan requests double and triple for high- and middle-value residential property classes, respectively, the total loan requests remain under $10,000. Payable residential premiums fall by about 9%. This is the primary explanation for the 4% reduction in residential program costs. Payable commercial premiums fall by 24%, but this occurs primarily because the "substantial improvement" rule is not operational; when properties are substantially damaged while a community is in the emergency program, there is no basis for charging actuarial rates. Total commercial program costs rise by 8%.

The third model program is based on the SBA disaster loan regulations which were in effect at the time of this study. All property losses are assumed to qualify for twenty-year loans at 6⅝% annual interest. Under this program, residential participant costs amount to 63.4% of total program costs. Unlike the case of the insurance models, tax transfers play a significant role in determining loan program costs; nearly 75% of government costs go for such transfers to residential properties.

Tax transfers also play a significant rule in the commercial case. Average participant loan costs amount to $10,797 per property, but because of transfers, the net cost per property is

only $1,919. Nearly 84% of total program costs are paid by government tax transfers or interest rate subsidies.

The final program alternative is designed to reflect loan program regulations which were in effect following the 1972 tropical storm Agnes disaster. Loan interest rates are reduced to 1% and the first $5,000 of each loan request is "forgiven" as an outright grant. Loan maturities remain at twenty years.

Under this program, there is a major shift of disaster costs to the federal government. Compared with the unsubsidized loan program, residential participant costs fall by $347,632, or 87%. The government portion of total costs amounts to 92%. For commercial properties, participant costs are reduced from $63,334 to $3,640, a drop of 94%. Government costs account for 99.1% of the program total. A substantial portion of this change is attributable to the loan forgiveness grants, which account for 87% and 51% of total loan subsidy costs to residential and commercial properties, respectively.

In addition to the four programs already described, table 4 contains a special modified insurance program. The model approximates the operation of a program with emergency program coverage limits and with insurance rates corrected for differences between current actuarial rates and rates that would just cover expected losses as calculated in the simulation runs. Because one would ultimately expect rates to reflect expected losses in the long run, these adjustments to premium costs make this model most directly comparable to the loan program results.

When insurance rates are modified to reflect the expected level of damages over time, total insurance costs are approximately 20% less than total costs of the unsubsidized loan program. These adjustments, however, do little to affect the proportion of insurance program costs borne by property owners and the government.

Policy Conclusions

Although it is difficult to generalize from the results of one case study, this analysis does suggest several important aspects of current disaster relief policy which merit careful examination. For the individual, the simulation results present several important implications. Participant costs for both the emergency and regular insurance programs are about five times the participant costs of the subsidized loan program. Because this subsidized loan model is characteristic of past disaster assistance strategy, these results may partially explain other research findings that voluntary purchases of flood insurance have been relatively infrequent in the past (Kunreuther, Kunreuther et al.).

In the simulation model, care was taken to calculate correctly flood insurance premiums based on flood hazard studies and the NFIP rate manual. Nevertheless, the model results showed annual premiums to be much below and much above average claim costs for residential and commercial properties, respectively. While the evidence does not prove conclusively that current NFIP rates are actuarially unsound, it does suggest the possibility that the rates may be quite inaccurate for certain areas because they ignore specific local hydrologic factors. If insurance rates could be specialized to regional geographic and flooding conditions, serious inequities in premiums might be avoided. Insurance rates that reflect flood risk adequately are essential for sound floodplain management and increased program participation.

The study also demonstrated that, in general, the coverage provided under the emergency flood insurance program appeared sufficient to reimburse most flood losses up to the 100-year flood level; thus, the individual faces less than a 1% chance of ever needing the additional coverage available under the regular program. Currently, the extra coverage is sold at a fixed rate, so that the ratio of premium cost to expected loss increases with coverage. From the individual's perspective, this also makes the choice of insurance relatively less favorable to other alternatives. Thus, it may be necessary to reduce the cost of higher amounts of coverage in order to encourage property owners to insure their property at a high percentage of its value. Because actuarial rates for many properties in the study area were found to be less than emergency program rates, movement toward this goal might be facilitated by the conversion of similar communities from the emergency to the regular flood insurance program as soon as possible.

From a public perspective, these programs must be evaluated on the basis of both total program costs and distributional impacts. Once insurance rates are adjusted to reflect

expected annual losses, total insurance program costs are somewhat lower than the total costs of the loan programs. For the insurance alternatives studied, variations in premium subsidies change the distribution of costs between individuals and the government without affecting the total. In the loan programs, benefits and costs are not evaluated equally by both parties because of differentials in public and private opportunity-borrowing costs. Thus, loan subsidies can potentially increase total program costs, as well as affect their distribution.

In the study area, for example, the level of subsidy for residential properties is influenced tremendously by the size of the forgiveness grants and is relatively insensitive to changes in interest rates. The opposite is true for commercial properties: interest subsidies and the tax deductions are quite large. To achieve any desired level of subsidy to property owners, within a given tax structure, two policy instruments, interest rates and grants, must be manipulated simultaneously. An insurance subsidy, if one were desirable, could be achieved more directly by changing insurance premiums.

In conclusion, only a few of the policy issues involving disaster assistance programs have been examined; even for these it is difficult to generalize on the basis of case study research. Despite these limitations, the methodology developed here can be applied elsewhere and the study does highlight the economic variables built into present disaster assistance programs. Several potential sources of inequity have been suggested, thus providing topics for additional research in this area.

[*Received August 1978; revision accepted March 1979.*]

References

Dacy, Douglas C., and Howard Kunreuther. *The Economics of Natural Disasters.* New York: Free Press, 1969.

Friedman, D. G., and Tappan S. Roy. *Simulation of Total Flood Loss Experience of Dwellings on Inland and Coastal Flood Plains.* Hartford, Conn.: Travelers Insurance Co., Dec. 1966.

Haveman, R. H. "The Opportunity Cost of Displaced Private Spending and the Social Discount Rate." *Water Resour. Res.* 5(1969):947–57.

Hydrologic Engineering Center (HEC-II). *Water Surface Profiles, Users' Manual.* Davis, Calif.: U.S. Army Corps of Engineers, Oct. 1973.

Kunreuther, Howard. *Recovery from Natural Disasters: Insurance or Federal Aid?* Washington, D.C.: American Enterprise Institute for Public Policy Analysis, 1973.

Kunreuther, H., R. Ginsberg, L. Miller, P. Sagi, P. Slovic, B. Borkan, and N. Katz. *Disaster Insurance Protection: Public Policy Lessons.* New York: Wiley-Interscience, 1978.

Musgrave, Richard A., and Peggy B. Musgrave. *Public Finance in Theory and Practice.* New York: McGraw-Hill Book Co., 1976.

National Flood Insurers Association. *National Flood Insurance Program, Flood Insurance Manual.* Arlington, Va., Feb. 1975.

Rettger, Michael J. *An Economic Analysis of Alternative Federal Flood Damage Assistance Programs.* M.S. thesis, Cornell University, 1977.

Rettger, Michael J., and Richard N. Boisvert. *Economics of Federal Flood Insurance and Loan Programs.* New York Agr. Exp. Sta. SEARCH Bull., Agr. Econ. Vol. 6, No. 2, Cornell University, 1978.

Robillard, Paul D. *A Partial Flood Reduction Program for Binghamton, New York.* Deps. Agr. Econ. and Agr. Eng., Cornell University, 31 Aug. 1975.

Schaake, John C., Jr., and Myron B. Fiering. "Simulation of a National Flood Insurance Fund." *Water Resour. Res.* 3(1967):913–29.

Selby, Samuel M., ed. *Standard Mathematical Tables.* Cleveland, Ohio: Chemical Rubber Co., 1968.

Susquehanna River Basin Commission. "Flood Damages, Main Stem and Major Tributaries." Susquehanna River Basin Stud. Rep. on Sub-Study No. SS-Ce-3, Mechanicsburg, Pa., undated.

U.S. Congress, House of Representatives, Committee on Banking, Currency and Housing. *Federal Flood Insurance Program, Hearings befoe a Sub-committee of the House Committee on Banking, Currency, and Housing on H.R. 1677, H.R. 2459 and H.R. 3203.* 94th Congress, 1st Session, 17 Oct. 1975, 18 Nov. 1975, 2, 4 Dec. 1975.

U.S. Department of Commerce, Bureau of the Census. *United States Census of Housing: 1970,* vol. 5. Washington, D.C., Mar. 1973.

U.S. Department of Labor, Bureau of Labor Statistics. "Consumer Expenditures and Income, Details of Expenditures and Income, Total United States, Urban and Rural, 1960–61." *Survey of Consumer Expenditures, 1960–61.* Washington, D.C., May 1966.

U.S. Water Resources Council. *Guidelines for Determining Flood Flow Frequency.* Bull. No. 17, Mar. 1976.

Notes

Sensitivity of Efficient Frontiers Developed for Farm Enterprise Choice Decisions

Bryan Schurle and Bernard L. Erven

An efficient frontier provides information concerning the tradeoff between risk and return in farm enterprise choice decisions. If mean-variance analysis is used, the frontier is efficient in the sense that it represents a series of farm enterprise combinations, each enterprise combination having minimum risk (variance of returns) for a specified level of return. Anderson, Dillon, and Hardaker provide a discussion of the different types of frontiers and the different methods of deriving them.

Development of efficient frontiers is particularly helpful when the risk among enterprises varies substantially (Schurle and Erven). However, efficient frontiers do not provide information about near-optimal enterprise combinations. According to Heady and Candler the optimum solutions in linear programming need not be optimum for other criteria. Since farmer's utility functions cannot be completely specified in terms of risk and returns, decision makers and researchers should be interested in farm plans slightly different from those on the frontier in terms of risk and return levels. The usefulness and uniqueness of frontiers as a decision aid would be reduced substantially if these near optimal solutions included substantially different enterprise combinations. Other considerations of the manager may overshadow the differences in risk between near-optimal enterprise combinations off the frontier and the optimum plan on the frontier.

Related work of an experimental nature has been done previously on the impacts of estimation error on the development of efficient frontiers. Frankfurter, Phillips, and Seagle found that the impacts of errors in estimating the mean, variance, and covariance are so strong that the usefulness of some mean-variance approaches to portfolio selection is brought into question. The model used in this analysis is somewhat related to other mean-variance approaches; thus, the possibility of carryover of these results to the model used here does exist. In this article an empirical approach to the sensitivity issue similar to a procedure used by Levy and Sarnat is employed.

The issue of frontier sensitivity, indicating how greatly farm plans just off the frontier differ from the minimum risk farm plans on the frontier, needs to be analyzed. In this paper, we report on the sensitivity of efficient frontiers developed in a farm enterprise choice study. Specifically, we address the question of how much change in risk accompanies an enterprise combination change when expected return is held constant.

Problem Setting

The problem involves choices between cash grain crops (corn, soybeans, and wheat) and specialty crops (processing tomatoes and cucumbers) in Ohio. The budgeted net returns in table 1 show the relatively high returns associated with tomatoes and cucumbers. However, farmers considering adding these enterprises or expanding current acreage have a major concern with risk. Yields may vary substantially due to interactions of complex production technology, seasonal labor supply, and weather. Substantial yield variation results in much greater annual variation in returns for specialty crops than for grain crops (see table 1).

Risk is an important factor in farmers' decisions because of the trade-offs between the higher returns and higher risk of the specialty crops and the lower returns and lower risk of the grain crops. The coefficient of variation allows a comparison of the risk associated with different enterprises. Table 1 shows that the coefficients for the grain crops are substantially below those for tomatoes and cucumbers. It is these differences among the crops which cause risk to be a major concern for farmers.

Farmers can reduce risk by diversifying among these enterprises. The correlation coefficients between returns for different enterprises indicate that only hand and mechanically harvested tomatoes are significantly correlated. Wheat returns tend to be negatively correlated with other returns, but not at a significant level. All correlations between enterprises are built into the model.

Bryan W. Schurle is an assistant agricultural economist with the Kansas Agricultural Experiment Station, Kansas State University, and Bernard L. Erven is a professor, Department of Agricultural Economics and Rural Sociology, Ohio Agricultural Research and Development Center and the Ohio State University.

Contribution No. 79-30-t, Department of Agricultural Economics, Agricultural Experiment Station, Kansas State University. Approved for publication as Journal Article No. 195-78 of the Ohio Agricultural Research and Development Center.

The authors wish to express appreciation to Edward Ives, Orlan Buller, Don Pretzer, and two anonymous *Journal* reviewers for helpful comments on earlier drafts of this article. Any remaining errors are the responsibility of the authors.

Table 1. Descriptive Statistics for Alternative Enterprises

Enterprise	Return above Variable Cost Per Acre	Standard Deviation of Return	Coefficient of Variation
	($)	($)	
Corn	172	50	.29
Soybeans	122	39	.32
Wheat	90	28	.31
Mechanically harvested tomatoes	593	344	.58
Hand-harvested tomatoes	335	268	.80
Cucumbers	250	272	1.09

Model Formulation

Given the characteristics of this problem, an operational procedure was needed which permitted the handling of a complex set of enterprise alternatives, explicit treatment of risk and the development of practical farm enterprise choice guidelines. The modified linear-programming alternative, the MOTAD model proposed by Hazell, was chosen. The MOTAD model minimizes a measure of dispersion which can be converted to a variable comparable to the variance used in quadratic programming. The results provide data for an EA frontier very similar to the EV frontier from quadratic programming (Thompson and Hazell). The MOTAD model has been used previously in attempts to reflect accurately producer behavior (Simmons and Pomareda, Brink and McCarl).

The basic linear-programming matrix models a 600-acre representative farm with the resources to produce corn, soybeans, wheat, mechanically harvested tomatoes, hand-harvested tomatoes, and hard-harvested cucumbers. Additional activities also were included for hiring labor, land preparation, and other support services. The constraints of the model included land, and the limiting factors of labor, machinery capacity, and field time associated with critical spring planting and fall harvesting periods.

Several activities were used to represent each enterprise in the model. For example, corn and soybeans could be planted in any of six spring time periods and harvested in any of the three fall time periods. This resulted in eighteen activities to represent corn and eighteen to represent soybeans. A portion of the Ohio Crop Model, a modified version of the Purdue Top Farmer Model, was used for the corn, soybeans, and wheat components of this model. Other enterprises were handled in a similar manner. Tomatoes harvested by machine were represented by thirteen activities and tomatoes harvested by hand were represented by ten activities. The returns associated with activities varied depending on the estimated yield for each planting and harvesting period combination.

Formulation of the MOTAD model was accomplished by adding eight years of historical product price and yield data to the basic linear-programming matrix (Schurle). These historical data were collected from three farms. The farms were similar in that they were located near each other, they had similar soil types, and the managers had reputations of being excellent. Homogeneity of these three farms was necessary because data for different enterprises were taken from each farm. One farm provided data on mechanically harvested tomatoes and soybeans, one farm provided data on hand-harvested tomatoes and cucumbers, and one provided data on corn and wheat. These historical data provided an eight-year series for all enterprises. The series was constructed from three farms because not all the farms had all the enterprises in each of the eight years. Detailed cost data for each of the years were not available from these farms. Therefore, product price trends were removed and costs were assumed to be constant over the eight-year period. The presence of a trend in yields was not verified, so no yield trends were removed. Consequently, the gross margin deviations measure the dispersion around a trend line for year-to-year product price but not year-to-year cost or yield variation (Chen). This was justified because the sources of risk of importance in this study are yields and product prices.

The data allowed development of gross margin deviations for each enterprise. However, time-series data on yields were not available for each activity (representing different planting and harvesting dates) in the model. Consequently, the same gross margin data were used for each activity of an enterprise. This caused each activity of an enterprise to have the same variance of returns even though some activities representing an enterprise were less profitable than others due to less than optimal planting and harvesting dates.

These data were included in the following MOTAD model formulation:

(1) $$\text{Minimize } \sum_{h=1}^{s} y_{\bar{h}},$$

such that

(2) $$\sum_{j=1}^{n} (c_{hj} - g_j)x_j + y_{\bar{h}} \geq 0$$

(for $h = 1, 2, \ldots, s$), and

$$(3) \quad \sum_{j=1}^{n} f_j x_j = I \qquad (\text{for } I = 0 \text{ to unbounded}),$$

$$(4) \quad \sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad (\text{for } i = 1, 2, \ldots, m), \text{ and}$$

$$(5) \qquad x_j, y_{\bar{h}} \geq 0 \qquad (\text{for all } h, j),$$

where $y_{\bar{h}}$ is the absolute value of the sum of the negative gross margin deviations in observation h; c_{hj} is the gross margin (gross revenue per acre—variable costs per acre) for the jth activity on the hth observation; g_j, the average gross margin for the jth activity; x_j, the level of the jth activity (usually in acres); f_j, the expected net return of the jth activity; I, the expected net return; a_{ij}, the technical requirements of the jth activity in the ith constraint; b_i, the ith constraint level; s, the number of years; n, the number of activities in the basic LP model; and m, the number of constraints in the basic LP model.

This model minimizes risk for each level of I (total returns above variable costs) specified in equation (3). The model minimizes risk as measured by the sum of the absolute values of the negative total gross margin deviations. Essentially this minimizes the standard deviation of returns to the farm measured by the estimator

$$D\left[\frac{\pi s}{2(s-1)}\right]^{\frac{1}{2}},$$

where s is the number of years in the sample and D is the estimated mean absolute deviation in returns to the farm (Hazell). In order to minimize risk while achieving a specified return level, the model selects enterprise combinations that are least risky (as measured by variance in annual returns) and/or that have negatively (or less positively) correlated returns. Return to the farm (I) is parameterized, resulting in a minimum risk farm organization for each specified level of return. The return, risk coordinates can be graphed as in figure 1 (the solid curve) to show the efficient frontier facing a farm manager with a given resource base. The decision maker can then choose an enterprise combination and return-risk situation which is consistent with his risk preference and goals. If the farm plan chosen is off the frontier, there is an increase in risk with no compensating increase in returns.

Results

In the first phase of the analysis, all cash grain and specialty crop enterprises were allowed to enter the model. The resulting efficient frontier is illustrated in figure 1 as a solid curve. Net return above variable costs was varied in $5,000 intervals. There is a specific farm plan associated with each point on the frontier. However, for purposes of brevity, only selected farm plans for the frontier are shown in table 2. This table also shows the coefficient of variation and the standard deviation of net return for the farm.

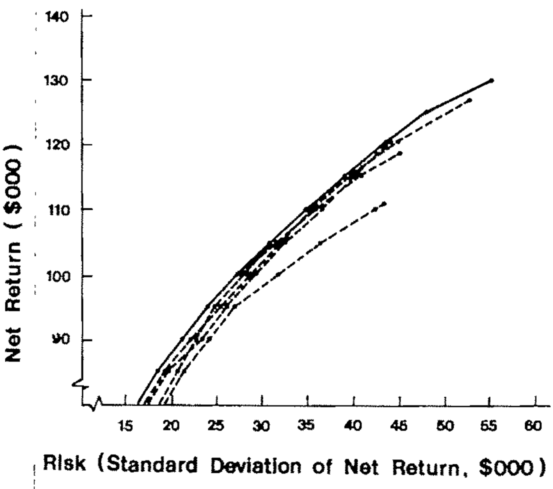


Figure 1. Minimum risk-efficient frontier (solid curve), and near optimal frontiers (dashed curves)

It can be observed readily from table 2 that diversification has a major impact on risk and net return. The more diversified farm plans have lower levels of net return and risk. The trade-off between returns and risk is captured by the coefficient of variation. As net return decreases, the coefficient of variation is reduced which shows that risk per dollar of expected return is reduced.

Farm plans change considerably along the frontier. Table 2 shows that most acreage is committed to grain crops at lower return-risk levels and that specialty crops become increasingly important at higher return-risk levels.

Sensitivity of Frontier

We have shown the impacts of changes in enterprise combinations on both return and risk. We turn now to the sensitivity of the frontier which has been generated. Are there enterprise combinations substantially different from those in table 2 for each level of return which have inconsequential increases in risk? If there are, the approach we used for investigating enterprise choice under risk has not identified all the enterprise combinations of interest to decision makers.

The sensitivity question was investigated by restricting the model to the selection of enterprises in different subsets of all the enterprises considered. This method has been used previously in analyzing the effects of international diversification on investment portfolio risk (Levy and Sarnat). Each subset, formed by excluding one enterprise, resulted in a separate frontier. Each new frontier falls to the right of the original frontier, indicating increased risk due to the different enterprise combi-

Table 2. Enterprise Combinations of Grain and Specialty Crops

Return[a]	Corn	Soybeans	Wheat	Mechanically Harvested Tomatoes	Hand-Harvested Tomatoes & Cucumbers	Standard Deviation of Net Return	Coefficient of Variation
($000)	(acres)					($000)	
85	221	144	230	0	5	19	.22
95	186	274	99	0	41	24	.25
105	245	302	0	15	39	31	.29
115	341	172	0	27	60	39	.34
125	437	75	0	72	16	48	.38
130	483	0	0	85	32	56	.43

[a] Return above variable costs. The estimated fixed cost of land and machinery for this representative farm is $97,000.

nation on the new frontier. These new frontiers are represented as dashed lines in figure 1. All frontiers remain relatively close together with the exception of the frontier derived for no corn. The no corn frontier drifts away from others. The other frontiers tend to converge as returns increase.

Table 3 shows the enterprise combinations for each of the frontiers at the $95,000 return level. The results in table 3 show that substantial differences exist among the enterprise combinations. Corn varies from 114 to 442 acres, soybeans from 142 to 453 acres, wheat from 60 to 158 acres and hand-harvested tomatoes and cucumbers from 0 to 67 acres in the plans where each is allowed. These differences should be important to a farmer. For example, the "no soybeans" farm plan in the table consists of corn and wheat only, while the "minimum risk" farm plan includes corn, soybeans, wheat, and a substantial amount of hand-harvested tomatoes. These two farm plans are different from a farmer's viewpoint because tomatoes are included in one combination and not the other. Most important, these significant enterprise combination changes resulted in little additional risk at this return level. The next to last column in table 3 shows that the increase in standard deviation of net return varied from $690 to $3,500. These are relatively small increases (3%–15%) when compared to the level of standard deviation, which ranged from $23,910 to $27,410.

The sensitivity of risk was also investigated at other return levels. However, for the higher return portion of the frontier, enterprise specialization sometimes caused one of three results when risk sensitivity was investigated. First, a frontier developed with a certain restriction may not reach the high return levels under consideration. As an example, table 4 shows that the "no corn" frontier does not reach the $115,000 return level. A second result occurring in some situations was that the restriction placed on an enterprise did not change the farm plan from the "minimum risk" farm plan.

Table 3. Enterprise Combinations Which Result in a Net Return of $95,000

Enterprise Restriction	Corn	Soybeans	Wheat	Mechanically Harvested Tomatoes	Hand-Harvested Tomatoes & Cucumbers	Standard Deviation of Net Return	Change in Standard Deviation	Percentage Change in Standard Deviation
	(acres)					($000)		
None (minimum risk)	186	274	99	0	41	23.91	—	—
No corn	0 (−186)[b]	453 (+179)	60 (−39)	21 (+21)	66 (+25)	27.41	3.50	14.6
No soybeans	442 (+256)	0 (−274)	158 (+59)	0	0 (−41)	25.58	1.67	7.0
No wheat[a]	114 (−72)	362 (+88)	0 (−99)	0	67 (+26)	25.12	1.21	5.1
No hand-harvested tomatoes	311 (+125)	142 (−132)	137 (+38)	9 (+9)	0 (−41)	24.60	.69	2.9
No machine-harvested tomatoes	186 (0)	274 (0)	99 (0)	0 (0)	41 (0)	23.91	0	0

[a] 56 acres were rented out.
[b] Numbers in parentheses are changes in acres from minimum-risk enterprise combination.

Table 4. Enterprise Combinations Which Result in a Net Return of $115,000

Enterprise Restriction	Corn	Soybeans	Wheat	Mechanically Harvested Tomatoes	Hand-Harvested Tomatoes & Cucumbers	Standard Deviation of Net Return	Change in Standard Deviation	Percentage Change in Standard Deviation
	(acres)					($000)		
None (minimum risk)	341	171	0	27	60	38.99	—	—
No corn[a]	—	—	—	—	—	—	—	—
No soybeans	476 (+135)[b]	0 (−171)	60 (+60)	30 (+3)	35 (−25)	39.57	.58	1.5
No wheat	341 (0)	171 (0)	0 (0)	27 (0)	60 (0)	38.99	0	0
No hand-harvested tomatoes	318 (−23)	225 (+54)	0 (0)	57 (+20)	0 (−60)	39.34	.35	.9
No machine-harvested tomatoes	487 (+146)	22 (−149)	0 (0)	0 (−27)	92 (+32)	40.17	1.18	3.0

[a] The frontier derived for no corn did not reach $115,000 return level.
[b] Numbers in parentheses are changes in acres from minimum-risk enterprise combination.

Thus, risk comparisons could not be made. As an example, the "minimum risk" farm plan at the $115,000 return level in table 4 contains no wheat. So when wheat is not allowed in the farm plan, the new farm plan is the same as the "minimum risk" farm plan. A third result was that the enterprise restriction caused relatively smaller changes in farm plan, resulting in a correspondingly small increase in risk. As an example, the "no hand-harvested tomato" frontier in table 4 shows that corn acreage changed 23 acres; soybeans, 54 acres; wheat, 0 acres, mechanically harvested tomatoes, 20 acres; hand-harvested tomatoes and cucumbers, 60 acres; and the resulting change in standard deviation was $350. These results, as well as the results at other return levels reinforce the conclusion that major farm plan changes often are accompanied by relatively small risk changes for a fixed return level.

The ultimate determination of the significance of these increases in risk depends on the utility function of the producer. Utility functions presumably contain a number of variables in addition to profit and risk, both of which are analyzed in this model. Profit always has been of paramount importance, and risk in many instances, including this one, must be considered. However, the increases in risk as one moves from the frontier may be less important in this case than other considerations such as management requirements, need to manage migrant labor for specialty crops, or the prestige of producing certain crops.

Comparisons can also be made between non-optimal farm plans. There are even greater differences among these farm plans with extremely small differences in risk. Comparisons between the "no soybeans" farm plan and the "no hand-harvested tomato" farm plan in table 4 shows extreme differences in farm plan and only a $.23 difference in standard deviation. This indicates that once off the frontier, farmers may have many different farm plans to choose from with nearly negligible differences in risk.

Summary and Conclusions

The sensitivity of the efficient frontier for a particular farm enterprise choice problem has been examined. These results point out the need for not blindly using the farm organizations prescribed by the model. It appears appropriate to investigate only the more general trends in return, risk, and enterprise combinations within this model.

The results also cause concern about the usefulness of the model in predicting farmer behavior. How sophisticated can farmers be in choosing least-risk farm plans without the aid of these models? They probably cannot be very sophisticated and thus, in many cases, can only come close to the least-risk farm plan by some intuitive feel. If the farmers only come "close," and such wide differences in farm plans occur "close" to the frontier, how accurate can models of this type be in predicting farmer behavior?

We cannot be conclusive about the extent to which our findings can be generalized to choice problems involving other enterprises or other similar models. Much additional work needs to be done investigating the problems reported here and the causes of these problems. The problems may stem from the complexity of the model, the lack of data for each activity representing an enterprise, or the

length of the time-series data. However, the problems also may be a result of more basic difficulties with models of this type. Although not conclusive, the results presented here may add empirical strength to the conclusions of Frankfurter, Phillips, and Seagle that the usefulness of such techniques may be in doubt. Although the results do not indicate where the weakness in the method lies, with the available data in this study, there is basis to question the quality of decisions made using the efficient frontier.

[*Received July 1978; revision accepted February 1979.*]

References

Anderson, Jack R., John L. Dillon, and J. Brian Hardaker. *Agricultural Decision Analysis*. Ames: Iowa State University Press, 1977.

Brink, Lars, and Bruce McCarl. "The Tradeoff between Expected Return and Risk among Cornbelt Farmers." *Amer. J. Agr. Econ.* 60(1978):259–63.

Chen, Joyce T. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty: Comment." *Amer. J. Agr. Econ.* 53(1971):662–64.

Frankfurter, George M., Herbert E. Phillips, and John P. Seagle. "Portfolio Selection: The Effects of Uncertain Means, Variances, and Covariances." *J. Financ. and Quant. Anal.* 4(1971):1251–62.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1971):53–62.

Heady, O., and Wilfred Candler. *Linear Programming Methods*, pp. 198. Ames: Iowa State University Press, 1958.

Levy, Haim, and Marshall Sarnat. "International Diversification of Investment Portfolios." *Amer. Econ. Rev.* 60(1970):668–75.

Schurle, Bryan W. "An Analysis of the Return-Risk Tradeoffs Associated with Tomato Production in Northwestern Ohio." Ph.D. thesis, Ohio State University, 1977.

Schurle, Bryan W., and Bernard Erven. "The Trade-off between Return and Risk in Farm Enterprise Choice." *N. Cent. J. Agr. Econ.* 1(1979):15–21.

Simmons, Richard L., and Carlos Pomareda. "Equilibrium Quantity and Timing of Mexican Vegetable Exports." *Amer. J. Agr. Econ.* 57(1975):472–79.

Thompson, K. J., and P. B. R. Hazell. "Reliability of Using the Mean Absolute Deviation to Derive Efficient *E,V* Farm Plans." *Amer. J. Agr. Econ.* 54(1972):503–06.

The Effects of Trade Intervention on International Price Instability

Malcolm D. Bale and Ernst Lutz

Price instability has been an issue of long concern to economists and recently has received increased attention, mainly because of economic events taking place in the world during the 1970s. Much of the discussion has occurred in relation to agricultural commodities where random prices, reflecting stochastic fluctuations in supply and demand, are often of major significance. At different phases of price fluctuations, different groups become more vocal and more concerned about price movements—rising prices affect consumers and importing nations, whereas falling prices are of vital interest to producers and exporting countries. It is, perhaps, from such interactions and competing interests that the demands of developing countries for an international buffer fund to stabilize major export commodities have arisen.

Instability originates basically from two sources: real and policy-induced ones. Natural random factors influence both supply and demand of commodities. Production is affected by weather, disease, technological change, and input availability, while demand varies due to fluctuating income and taste changes. Stochastic demand and supply, in turn, cause prices to fluctuate. Price variability can be decreased through stabilization policies via buffer stocks and price forecasting, or it can be increased via policy measures affecting foreign trade. While it has long been recognized that international trade distortions which partially or totally insulate an importing country from the rest of the world have the effect of throwing the total price adjustment burden onto the rest of the world—often increasing the amount of price instability compared to that which would prevail under free trade—there has been little formal analysis of this phenomenon. Both Johnson and Schultz have stated recently that trade barriers increase price instability in world markets, while Shei and Thompson have simulated the impact of United States export controls and a change in Soviet import policy on world wheat prices in a quadratic wheat trade model under alternative trade policy assumptions.

The question of price instability induced by trade restrictions is particularly topical. Recently several international organizations (UNCTAD, IWC, FAO) have discussed the effects of price instability on export receipts in developing countries and its consequent effect on development. Many countries are studying commodity buffer stock plans in order to stabilize prices, and GATT members currently are attempting to liberalize trade at the Geneva multilateral trade negotiations. Thus, gaining insights into the causal effect of trade restrictions on price instability has considerable pragmatic appeal.

The purpose of this paper is to examine formally the effects of different trade intervention policies on international price instability. Our results show that some trade barriers have no impact on world price instability, while other types of restrictions transfer different degrees of instability from one country to the other. The paper uses a two-country, one-commodity, equilibrium model of trade to show that price instability generated by random supply fluctuations in the importing country can be amplified by various trade restrictions. The analysis is general, so that stochastic disturbances of supply and demand functions in both exporting and importing countries are considered simultaneously in order to demonstrate how and to what extent distortions affect price instability under constant exchange rates. Finally, some concluding comments are offered. (See Bale and Lutz for an expanded version of this paper and a simplified diagrammatic analysis.)

Mathematical Framework

Consider the following linear two-country model where demand in countries 1 and 2 is given by

$$(1)\qquad d_i = a_i - b_i P + \delta_i,$$

$i = 1, 2$, and supply is given by

$$(2)\qquad s_i = \alpha_i + \beta_i P + \epsilon_i,$$

$i = 1, 2$, where: d_i is demand in country i; s_i, the supply in country i; and P is price. The terms a_i, b_i, α_i, β_i are fixed parameters, and δ_i and ϵ_i denote random variables distributed as $N\ (O, \sigma_{\delta_i})$ and $N\ (O, \sigma_{\epsilon_i})$, respectively.

Free Trade

Under free trade, aggregate excess demand is zero, i.e.,

$$(3)\qquad \sum_i d_i - \sum_i s_i = 0,$$

Malcolm D. Bale and Ernst Lutz are economists at the World Bank.

The views expressed are those of the authors and not necessarily those of the World Bank.

The authors wish to thank an anonymous referee for constructive and detailed comments, and Debbie Kreamer for skilled typing. Any remaining errors are the responsibility of the authors.

$i = 1, 2$. From equation (3), the equilibrium price can be found to be

$$P_w = \sum_i \frac{a_i - \alpha_i + \delta_i - \epsilon_i}{b_i + \beta_i}, \tag{4}$$

$i = 1, 2$, and hence the variance of the free trade world market price is

$$\sigma_{P_w} = \sum_i \frac{\sigma_{\delta_i} + \sigma_{\epsilon_i}}{(b_i + \beta_i)^2}, \tag{5}$$

$i = 1, 2$, provided that s_i and ϵ_i are independently distributed.

Specific Tariff

The price P_2 in country 2 (the importing country) is equal to the price P_1 in country 1 (the exporting country) plus t, i.e.,

$$P_2 = P_1 + t. \tag{6}$$

Equation (6) is based on the assumption that the elasticity of supply of imports is infinite. Inserting into (3), and solving for P_1, P_2, we obtain

$$P_1 = P_w - t\frac{(b_2 + \beta_2)}{b_1 + b_2 + \beta_1 + \beta_2}, \tag{7}$$

$$P_2 = P_w + t\frac{(b_1 + \beta_1)}{b_1 + b_2 + \beta_1 + \beta_2}. \tag{8}$$

From (7) and (8) it can be seen that the price variance in both countries is equal to that in (5), i.e., equal to the free trade variance. The introduction of a specific tariff does not change the degree of price instability, or, in other words, a specific tariff transmits fluctuations so that a shock in one part of the system is absorbed by the whole system (table 1).

Ad Valorem Tariff

An ad valorem tariff is proportional to the export price and can be described by the following conditions:

$$P_2 = P_1\,(1 + t), \tag{9}$$

where t in this case is the tariff rate. Inserting (9) into (3), the price in the exporting country is found to be

$$P_1 = \sum_i \frac{a_i - \alpha_i + \delta_i - \epsilon_i}{b_i + \beta_i + t(b_2 + \beta_2)}, \tag{10}$$

$i = 1, 2$, and hence

$$\sigma_{P_1} = \sum_i \frac{\sigma_{\delta_i} + \sigma_{\epsilon_i}}{[b_i + \beta_i + t(b_2 + \beta_2)]^2}, \tag{11}$$

From equation (11) we see that for $t > 0$, $\sigma_{P_1} < \sigma_{P_w}$. That is, the imposition of an ad valorem (by an importing country) reduces the price variability in the exporting country. This is the case because the ad valorem tariff discourages imports when the export price is rising, and thus it has a stabilizing effect.

The price variance in country 2 is

$$\sigma_{P_2} = \sigma_{P_1}\,(1 + t)^2. \tag{12}$$

Comparing σ_{P_2} with the variance of price prevailing under free trade, we find

Table 1. The Effects of Trade Policies on Price Instability in Exporting and Importing Countries

	Degree of Price Instability in Comparison with the Instability under Free Trade[a]	
Trade Policy of Importing Country	Exporting Country	Importing Country
Specific tariff	same	same
Ad valorem tariff	smaller	larger
Fixed quota	generally larger	generally larger
Proportional quota	generally larger	generally larger
No trade	generally larger	generally larger
Price fixing	larger	smaller (= 0)
Variable levy	larger	smaller
Trade Policy of Exporting Country		
Specific tariff	same	same
Ad valorem tariff	smaller	larger
Fixed quota	generally larger	generally larger
Proportional quota	generally larger	generally larger
No trade	generally larger	generally larger
Price fixing	smaller (= 0)	larger
Export controls	smaller	larger

[a] By using the degree of price instability under free trade as a basis for comparison, we do not intend to imply that the free-trade price variance is necessarily optimal in a welfare sense.

$$(13) \qquad \frac{\sigma_{P_2}}{\sigma_{P_w}} = \frac{[k + t(b_1 + \beta_1)]^2}{k^2} > 1,$$

where, for convenience, k equals $b_1 + b_2 + \beta_1 + \beta_2 + t(b_2 + \beta_2)$. Thus, an ad valorem tariff increases the price instability in the (importing) country which imposes the tariff. Also, the variance of price increases with an increasing tariff rate and with increasing slopes of the supply and demand function in the exporting country.

Fixed Quota

The imposition of a quota, $\bar{q}$, in a two-country trading world results in the following equilibrium prices and price variances.

$$(14) \qquad P_1 = \frac{a_1 - \alpha_1 + \delta_1 - \epsilon_1 + \bar{q}}{b_1 + \beta_1},$$

$$\sigma_{P_1} = \frac{\sigma_{\delta_1} + \sigma_{\epsilon_1}}{(b_1 + \beta_1)^2}, \text{ and}$$

$$(15) \qquad P_2 = \frac{a_2 - \alpha_2 + \delta_2 - \epsilon_2 - \bar{q}}{b_2 + \beta_2}, \text{ with}$$

$$\sigma_{P_2} = \frac{\sigma_{\delta_2} + \sigma_{\epsilon_2}}{(b_2 + \beta_2)^2}.$$

Thus, it is clear that under a quota system no instability is transmitted and that all disturbances are absorbed in the country where they originated as in the no trade case.

Comparing the variance of price in the exporting country under a quota system with that under free trade, it is found that

$$(16) \qquad \sigma_{P_1} > \sigma_{P_w},$$

since

$$(\sigma_{\delta_1} + \sigma_{\epsilon_1})[(b_2 + \beta_2)^2 + 2(b_1 + \beta_1)(b_2 + \beta_2)] - (\sigma_{\delta_2} + \sigma_{\epsilon_2})(b_1 + \beta_1)^2 > 0.$$

From equation (16) we see that σ_{P_1} is larger than the free-trade price variance when the slopes of the supply and demand functions as well as the variances in both countries are of equal size (or similar in magnitudes). The reason for this is that in a system where disturbances are not correlated, free trade tends to even out fluctuations. The variance of price σ_{P_1} would be smaller than σ_{P_w} only where the demand and supply variances in the importing country are much larger than those in the exporting nation or where supply and demand elasticities in the exporting country are much larger than those in the importing country. Similar arguments can be made for a comparison of σ_{P_2} and σ_{P_w}.

Equivalence of Tariffs and Quotas

The notion of equivalence between tariffs and quotas is widespread in the literature on trade theory. Bhagwati (1965) showed that for the equivalence to hold, the assumption of universal competitiveness must be used and that equivalence characteristics break down when monopoly elements are introduced. Further refinements followed in later papers by Bhagwati (1968) and McCulloch, and the nonequivalence of tariffs and quotas assuming retaliation was analyzed by Rodriguez using a general equilibrium approach. Within the partial equilibrium framework, Fishelson and Flatters, Pelcovits, and, more recently, Dasgupta and Stiglitz have extended the analysis to uncertainty. They each found and analyzed cases in which the widely held equivalence of tariffs and quotas collapses. Our analysis presents yet another example of the nonequivalence of tariffs and quotas. From equations (5) and (16), we demonstrate that with a pure tariff, instability is transmitted freely among countries; whereas, under a pure quota, it is not transmitted at all.

Proportional Quota

A proportional quota is a system in which import rights are assigned to producers or consumers in proportion to their individual production or consumption of the restricted goods. For the analysis of the effects of a proportionally distributed quota and a comparison with a tariff or equivalent quota see McCulloch and Johnson. For our analysis we assume here a system that guarantees domestic producers in the importing country a constant market share. The quota is, therefore, defined as

$$(17) \qquad Q = cd_2,$$

where $o < c < 1$.[1] An equivalent proportional quota policy for the exporting country would determine a constant share of production to be exported. Using (17) the equilibrium price for the importing country is found to be

$$(18) \quad P_2 = \frac{a_2(1 - c) - \alpha_2 + \delta_2(1 - c) - \epsilon_2}{b_2(1 - c) + \beta_2},$$

and, hence, the variance is

$$(19) \qquad \sigma_{P_2} = \frac{\sigma_{\delta_2}(1 - c)^2 + \sigma_{\epsilon_2}}{[\beta_2 + b_2(1 - c)]^2}.$$

The price variance for a proportional quota policy is larger than the price variance under a fixed quota if

$$(20) \quad \beta_2 \sigma_{\delta_2} [\beta_2(c - 2) + 2b_2(1 - c)] + b_2 \sigma_{\epsilon_2} [b_2(2 - c) + 2\beta_2] > 0.$$

The algebraic expression in (20) increases for increasing b_2 and σ_{ϵ_2} and for decreasing β_2 and σ_{δ_2}.

[1] Sometimes a policy is defined such that $Q \leq cd_2$, i.e., domestic producers not only have a guaranteed share of the domestic market, but their share can be increased through a reduction of the quota as dictated by the policy environment. Note also that for the cases where Q is less than cd_2, it is necessary to set Q equal to cd_2 in order to obtain an equilibrium solution.

From condition (20), we conclude that a proportional quota as defined above generally would increase the price variance in the importing country as compared to the free trade or the fixed-quota case. The reason is the quota introduces an additional disturbance into the system.

The imposition of a proportional quota in the importing country affects the exporting country such that

$$(21)\quad P_1 = \frac{a_1 + ca_2 - \alpha_1 + \delta_1 + c\delta_2 - \epsilon_1}{b_1 + cb_2 + \beta_1}, \text{ and}$$

$$(22)\quad \sigma_{P_1} = \frac{\sigma_{\delta_1} + c^2 \sigma_{\delta_2} \sigma_{\epsilon_1}}{(b_1 + cb_2 + \beta_1)^2}.$$

It can be shown that a proportional quota results in a reduction of the price variance in the exporting country as compared to the cases of no trade or the fixed quota for

$$(23)\quad b_2(\sigma_{\delta_1} + \sigma_{\sigma_1})(cb_2 + 2b_1 + 2\beta_1) - c\sigma_{\delta_2}(b_1 + \beta_1)^2 > 0.$$

From condition (23) we obtain the interesting result that the imposition of a proportional quota by the importing country generally results in the transmission of instability from the exporting to the importing country.

Price Fixing

In most state trading nations, but also in some other countries, internal prices are fixed by government policy. Trade is strictly controlled by the government, which allows only specific quantities to be imported, quantities which vary from year to year. For the cases where external prices rise above the internal price, a ban on exports coupled with import subsidies is needed to maintain the policy. If the price in the importing country is fixed at $\bar{P}_2$, the equilibrium price in the exporting country is

$$(24)\quad P_1 = \frac{\sum_i a_i + \alpha_i + \delta_i + \epsilon_i - \bar{P}_2(b_2 + \beta_2)}{b_1 + \beta_1},$$

$i = 1, 2$, and the price variance is

$$(25)\quad \sigma_{P_1} = \frac{\sigma_{\delta_1} + \sigma_{\delta_2} + \sigma_{\epsilon_1} + \sigma_{\epsilon_2}}{(b_1 + \beta_1)^2}.$$

From (25) we can see that all instability in the importing country has been exported to the exporting nation. Comparing σ_{P_1} with the variance of price under free trade, we obtain

$$(26)\quad \frac{\sigma_{P_1}}{\sigma_{P_{1C}}} = \frac{(b_1 + b_2 + \beta_1 + \beta_2)^2}{(b_1 + \beta_1)^2} > 1.$$

It is clear that this ratio increases when supply and demand in the importing country become more inelastic.

Variable Levy

As long as the export price is below the price in the importing country, the imposition of a variable levy has the same effect on instability as in a pure case of price fixing. In a case where the export price rises above the price determined by the importing country, the latter would import the commodity as in the free trade case up to the self-sufficiency price. Because the export price usually can be assumed to be below the price in the importing country, the latter can shift almost all internally created instability onto the external market.

Concluding Comments

In this paper we have demonstrated that various trade intervention policies have a very different effect in altering instability in one country and transmitting it to the rest of the world. The purpose of the note is to present a comprehensive analysis of different trade restrictions and to show how, and to what extent, they affect price instability.[2] For each of the trade intervention measures the resulting price variances are derived for both the exporting and the importing country.

What is the practical importance of this work? Governments seem interested in price stability, particularly for agricultural commodities. Yet they are interested primarily in internal stability rather than in global stability. In achieving internal price stability by various means governments throw adjustment onto the rest of the world. We have quantified the impact such actions will have on world and domestic price stability. Empirical calculations of these effects should be an important issue in trade negotiations. Not only may it be possible to appeal to a barrier-imposing country's international responsibility; but it is possible to demonstrate that for a given level of protection, some trade intervention policies generate a smaller impact on instability in the international community than others. There are other uses of the model. It also can be used to determine a mix of trade-restricting measures by different countries simultaneously. Thus, retaliation also could be analyzed and the resulting equilibrium price levels (if any) and the degrees of instability could be determined.

[Received September 1978; revision accepted November 1978.]

[2] An extension of this work, not considered here, involves a determination of the welfare consequences of each of these actions. Some cases are already discussed in the literature. Bieri and Schmitz have analyzed a case of tariffs and marketing boards; Hueth and Schmitz determined the welfare gains from price stabilization for free trade within a linear framework; Just et al. (1978) used a general nonlinear analysis for the free trade case; and Just et al. (1977) developed the distribution of the welfare gains from price stabilization with price fixing. For a review of the price stabilization literature, the reader is referred to Turnovsky's excellent survey.

References

Bale, M. D., and E. Lutz. "Trade Restrictions and International Price Instability." World Bank Staff Work. Pap. No. 303, Oct. 1978.

Bhagwati, J. "On the Equivalence of Tariffs and Quotas." *Trade, Growth, and the Balance of Payments*, ed. R. E. Baldwin. Chicago: Rand McNally & Co., 1965.

———. "More on the Equivalence of Tariffs and Quotas." *Amer. Econ. Rev.* 58(1968):142–46.

Bieri, J., and A. Schmitz. "Export Instability, Monopoly Power, and Welfare." *J. Int. Econ.* 3(1973):389–96.

Dasgupta, P., and J. Stiglitz. "Tariffs vs. Quotas as Revenue-Raising Devices under Uncertainty." *Amer. Econ. Rev.* 67(1977):975–81.

Fishelson, G., and F. Flatters. "The (Non-) Equivalence of Optimal Tariffs and Quotas under Uncertainty." *J. Int. Econ.* 5(1975):385–93.

Hueth, D., and A. Schmitz. "International Trade in Intermediate and Final Goods: Some Welfare Implications of Destablished Prices." *Quart. J. Econ.* 86(1972):351–65.

Johnson, D. G. "World Agriculture, Commodity Policy, and Price Variability." *Amer. J. Agr. Econ.* 57(1975):823–38.

Just, R. E., E. Lutz, A. Schmitz, and S. Turnovsky. "The Distribution of Welfare Gains from International Price Stabilization under Distortions." *Amer. J. Agr. Econ.* 59(1977):652–61.

———. "The Distribution of Welfare Gains from Price Stabilization: An International Perspective." *J. Int. Econ.*, 8(1978):551–63.

McCulloch, R. "When Are a Tariff and a Quota Equivalent?" *Can. J. Econ.* 6(1973):503–11.

McCulloch, R., and H. G. Johnson. "A Note on Proportionally Distributed Quotas." *Amer. Econ. Rev.* 63(1973):726–32.

Pelcovits, M. D. "Quotas versus Tariffs." *J. Int. Econ.* 6(1976):363–70.

Rodriguez, C. "The Non-equivalence of Tariffs and Quotas Under Retaliation." *J. Int. Econ.* 4(1974):295–98.

Shei, S. Y., and R. L. Thompson. "The Impact of Trade Restrictions on Price Stability in the World Wheat Market." *Amer. J. Agr. Econ.* 59(1977):628–38.

Schultz, T. W. "On Economics, Agriculture and the Political Economy." *Decision Making in Agriculture*, eds. T. Dams and K. E. Hunt. Oxford: Alden Press, 1978.

Turnovsky, S. J. "The Distribution of Welfare Gains from Price Stabilization: A Survey of Some Theoretical Issues." *Stabilizing World Commodity Markets*, eds. F. Gerard Adams and Sonia A. Klein. Lexington, Mass.: Lexington Books, 1978.

Import Tariffs and Price Formation in the World Wheat Market

Colin Carter and Andrew Schmitz

A theoretical analysis of price formation in the world wheat market has been presented by McCalla; Taplin; and Alaouze, Watson, and Sturgess. McCalla and Taplin based their models on a duopoly arrangement between the United States and Canada. These models were extended by Alaouze, Watson, and Sturgess to include Australia, and a theoretical model of triopoly pricing in the world wheat market was developed. Canada is assumed to act as a price leader in the triopoly, and it is concluded that producer prices in wheat-exporting countries will be higher under triopoly as opposed to duopoly pricing. The major thrust of these papers is that price formation in the world wheat market is largely determined by the major exporters.

The purpose of this paper is to suggest and empirically test an alternative hypothesis; namely, that world wheat prices are essentially determined by the major wheat importers. Two major importers—Japan and the European Economic Community (EEC)—are used as the focal point for the analysis. The authors believe the world wheat market is usually a buyer's rather than a seller's market. By arguing the market is usually dominated by buyers, it is recognized that there are periodical exceptions to the argument over time, the major one being the commodity boom period of 1973–74.

It is well known that the major importers are restricting trade in wheat. This paper suggests that the restrictive policies of the importers (whether consciously or not) are likely to result in a welfare gain to importing nations greater than that under free trade. This suggests that perhaps importing countries are using tariffs in an optimal sense (where all sectors of society are taken into account) rather than merely using them to protect domestic producers from low-priced competitive imports. This is not to argue that a duopoly or triopoly structure does not exist among the United States, Canada, and Australia but rather that the effect of such arrangements is minor relative to the buying power exerted by importers. Although this paper focuses on the world wheat market, the framework of analysis has application to other agricultural markets as well.

In light of the trade restrictions that have been set up by the major wheat importers in the international market, the effect of a duopoly or triopoly arrangement seems relatively minor. As an example of one such restriction, the Common Agricultural Policy (CAP) of the European Economic Community establishes a variable import levy on wheat (Riesenfeld). The levy ensures that wheat imports never sell below a target price which is set for Duisburg, in the Ruhr Valley, where wheat is in short supply. The variable levy serves to restrict severely the entry of wheat into the European market. A recent study by Cline et al. (p. 157) has estimated that in 1972 the tariff equivalent of the EEC variable levy on wheat was 109.5%. On the other hand, Japan has import quotas on wheat. As a result of the quota, Cline et al. (p. 167) have reported that in 1970 the import price of wheat was 24.5 yen per kilogram, while, at the same time, the Japanese domestic price was 60.2 yen per kilogram. These prices correspond to \$3.34 per bushel and \$8.20 per bushel, respectively.

Framework of Analysis

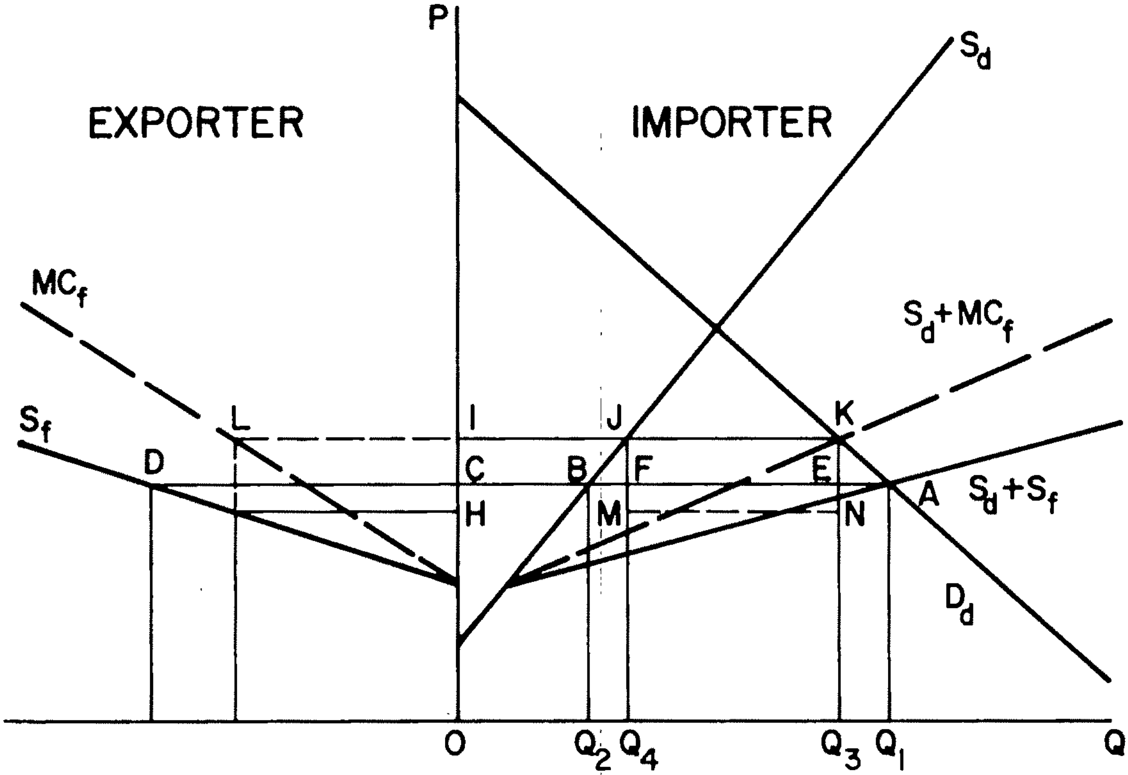
To study the structure of the international wheat market, the "optimal tariff" model is used as a framework. The optimal import tariff solution is given in figure 1 (see Enke). The supply schedule in the exporting country is given by S_f with MC_f being the marginal cost of importation when the importing country exerts monopsony power. In the importing country, S_d and D_d are the supply and demand schedules, respectively. Under free trade, imports are *BA*. However, the importing country can do better by imposing an optimum tariff. This solution is derived by summing $S_d + MC_f$. Imports are reduced to *JK*. In the importing country, producers gain *BCIJ*, consumers lose *IKAC*, and there is a gain in tariff revenue of *JKNM*. The gain in tariff revenue plus the producer gain more than offsets the consumer loss.

The model, as presented in figure 1, is used as a reference point for the hypothesized structure of the international wheat market in this study. That

---

Colin Carter is a postgraduate research agricultural economist and Andrew Schmitz is a professor of agricultural and resource economics, both at the University of California, Berkeley.

Giannini Foundation Paper No. 527. The comments of two anonymous *Journal* reviewers are gratefully acknowledged. Also, the authors thank A. McCalla, A. Sarris, and T. Josling for comments on an earlier draft of this paper given at the Stanford Food Research Institute and various economists of the U.S. Department of Agriculture for comments on a version of this paper given in Washington, D.C. Any remaining errors are the responsibility of the authors.



Source: Enke

Figure 1. The optimum tariff solution

is, the optimal tariff solution (i.e., what the world wheat prices would be if, in fact, importers pursued monopsony pricing) is computed. The results are then compared to the prices which actually prevail in the market.

Note that with the optimal tariff solution benefits accrue to more than just producers in the importing country; if the tariff revenue is redistributed to consumers, the country as a whole gains from the tariff. Thus, while a government may use tariffs primarily for the purpose of protecting producers, the net result may be an overall improvement in society's welfare if the tariff imposed is close to being optimal.

A Test of the Optimal Tariff Hypothesis

To test the model presented in figure 1, estimates of national supply and demand equations for wheat were obtained from an econometric study of the world wheat economy by the U.S. Department of Agriculture's Economic Research Service (ERS). From the estimates, aggregate supply and demand functions were computed for the major wheat exporters and importers. The estimated slope coefficients and elasticities provided by the ERS are not too dissimilar to those reported by Schmitz and Bawden. Because of the amount of time devoted to these studies, their estimates are likely as good as one can derive realistically for the world wheat economy using currently available econometric tools. The aggregate supply and demand curves were obtained by a horizontal summation of the countries' individual supply and demand curves. The intercept term of the importers' aggregate demand function was adjusted by the equivalent of a ten-year average of Russian and Chinese imports (approximately 10 million metric tons per annum) because it is difficult to estimate supply and demand functions for these countries due to a lack of data.

The aggregate empirical model is presented in figure 2 where D_E and S_E represent the empirical demand and supply functions of the major wheat exporters. The amount of excess supply of the major exporters is ES_E $(= S_E - D_E)$. The function marginal to ES_E is labeled MO_E. On the other side of the market, D_I and S_I represent the demand and supply functions of the major importers.

To integrate transportation costs into the analysis, the horizontal axis of the major exporters is shifted upward. The prices in figure 2 are in 1964–66 dollars.[1]

[1] Figures on transportation costs were obtained from the International Wheat Council. Freight rates for the 1964–66 period averaged between 15¢ and 40¢ per bushel for wheat for shipments from

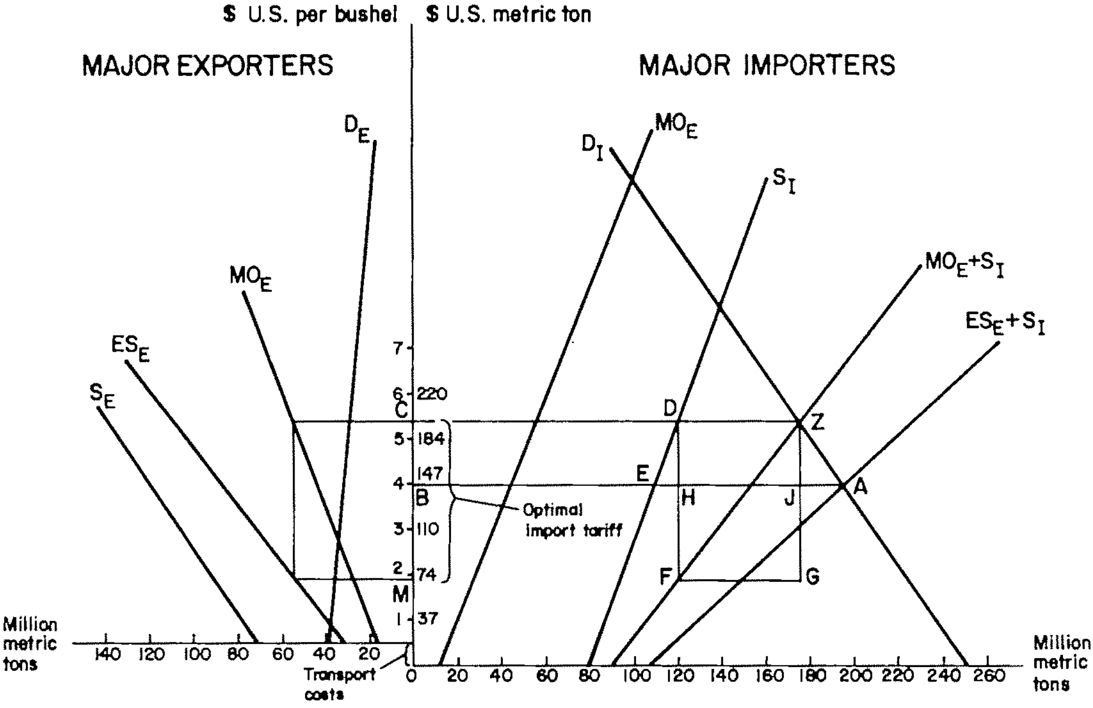


Figure 2. Empirical estimate of the optimal import tariff solution (1964–1966 prices)

From figure 2, free trade imports of wheat would equal *EA*, and the free trade price of wheat would be approximately *OB* per bushel. However, if, as hypothesized, the importers are exerting monopsony power in trade and, at the extreme, are imposing an optimum tariff, wheat imports would be restricted to *DZ*. Relative to the free trade position, the price in the importing countries would be raised from *OB* to *OC*, and the price of wheat in the exporting countries would be reduced from *OB* to *OM*. The world price of wheat would be *OM*. It is a depressed price due to the influence the importers have in the market.

To test informally the hypothesis that importers are exerting monopsony-like power in trade, one can compare actual prices (table 1) with the empirical estimates of the optimal tariff solution (figure 2). The export prices of Argentina, Australia, Canada, and the United States (table 1) should be compared for equivalence with the estimated price of *OM* (figure 2). Similarly, the support levels in Japan and in the EEC should be compared with the estimated *OC*. Because it is not argued that the "buyer's market" hypothesis in this study is completely robust over time, figures from table 1 should be compared with those from figure 2 for the period 1966–73 and 1976–77. This comparison abstracts from the 1973–74 to 1975–76 period as the "power" in the market temporarily reverted to the sellers as a consequence of the general commodity boom at the time.

Interestingly enough, the export prices for the 1966–73 and 1976–77 periods are very similar in table 1 and figure 2. The actual average export price for this period is $72 per tonne (average of the first four entries in the last row of table 2), while the estimated export (world) price is $70 per tonne (*OM*). The estimated and actual prices in the importing nations do not compare quite so favorably. The estimated price in the importing nations is approximately $198 per tonne. The average support price in Japan, $193, is very near the optimal $198 figure, but the support price in the EEC is less and is approximately equal to $113. The results suggest that perhaps, relative to Japan, the EEC is not taking full advantage of its position as a major wheat importer.

Because the actual prices in some cases are reasonably similar to the empirical estimates (figure 2), there is reason to argue that the major importers of wheat could be acting in a fashion similar to tacit collusive behavior and that they are effectively imposing close to an optimal import tariff on wheat. Even though there seems to be no formal collusive arrangement, it is conceivable that one of the major importers of wheat (e.g., Japan or the EEC) acts as a price leader in setting an optimal or nearly optimal tariff. Perhaps a mechanism used to achieve this is

Canada, Australia, and the United States to Rotterdam, India, and Japan. The authors chose to adjust the model in this study for transportation costs by assuming freight rates are set at 50¢ per bushel for all international shipments. This rate is likely an overestimate of actual rates but, in any case, does not adversely affect the results obtained.

Table 1. World Wheat Prices, 1966–67 to 1976–77

Crop year	Export Prices				Basic Support Levels[d]	
	Argentina Trigo Pan	Australia[a]	Canada[b]	United States[c]	Japan	EEC
	($U.S./metric ton)					
1966–67	59	63	72	67	140	[e]
1967–68	62	58	66	63	145	99
1968–69	58	58	68	63	152	99
1969–70	56	54	64	57	153	99
1970–71	57	58	67	63	164	99
1971–72	62	58	65	62	175	101
1972–73	86	91	92	92	217	114
1973–74	[f]	195	202	178	282	128
1974–75	163	167	198	170	334	148
1975–76	144	147	174	161	354	163
1976–77	104	113	130	118	401	183
Mean 1966–73 + 1976–77	68	69	78	73	193	113

Source: International Wheat Council.
[a] Australian Wheat Board selling price (f.o.b.); Australian Standard White.
[b] Canadian Wheat Board official "in store" price converted to f.o.b. at current fobbing rates (price basis: Thunder Bay); Canada Western Red Spring.
[c] F.o.b. Gulf; U.S. No. 2, Hard Winter.
[d] These prices are those used for government guaranteed prices.
[e] No data available.
[f] Due to the limited trading in this wheat in the 1973–74 crop year, no representative average export price is available.

the variable levy or the equivalent quota. Even though there is no evidence that overt collusion among importers exists, one could argue, as does Scherer, that collusion without formal agreement is both feasible and tempting.

The EEC, China, the USSR, and Japan account for between 30% and 40% of the world wheat imports, and they directly influence the world price of wheat. Table 1 and figure 2 suggest that the major importers are regulating consumption, production, and imports so that the least possible marginal cost to the group of obtaining wheat (shown by $MO_E + S_I$) is equal to its marginal value in consumption (shown by D_I) at point Z. As shown in figure 2, consumption of wheat in the importing countries under the optimal tariff is reduced to approximately 174 million metric tons per annum (CZ) with production of 119 million metric tons (CD). Imports of wheat to the group are approximately 55 million metric tons annually (DZ). The importers would set the optimum import tariff at close to $3.50 per bushel, and the exporting countries would receive approximately $1.90 per bushel net of transport costs. Under this solution, producers in the importing countries receive slightly over $5.00 per bushel.

The results generated from the model (figure 2) pertaining to volumes of wheat traded are very close to actual world wheat statistics. *World Wheat Statistics* reports that, for the period 1966–73 and 1976–77, the major wheat importers restricted their purchases to an average of 55.1 million metric tons per year. The model in this study predicted that, with an optimal tariff solution, imports of wheat to the group would be approximately 55 million metric tons annually.

Table 2. Welfare Gains to Wheat-Importing Nations with the Imposition of the Optimal Import Tariff

Welfare Effect	Net Gain
	$U.S. millions
1. Loss in consumers' surplus	−9,439
2. Gain in producers' surplus	5,971
3. Import tariff revenue	7,202
4. Net gain (3 + 2 − 1)	3,734

Source: Calculated.

Welfare Effects

Empirical estimates of the welfare gain accruing to the importing group as a result of the optimal tariff are shown in figure 2. Consumers in the importing countries lose a surplus equivalent to the area $CZAB$. On the other hand, producers in these countries gain a surplus equal to the area $CDEB$. Government revenue from the import tariff is equal to $DZGF$. Therefore, the total net gain to the importing nations is equal to the area $(HJGF) - [(DHE) +$

$(ZAJ)] > 0$. This estimated net welfare gain accumulated per annum by the wheat importers is shown in table 2 to be approximately $3.7 billion. These welfare estimates of the effects of trade restriction seem consistent with earlier studies by Johnson and by Cline et al.

Changing Structure of the Market

It has become apparent within the past ten years that the world wheat market is increasingly becoming a buyer's market. This trend lends credence to the hypothesis presented above. Recently, the production of wheat by the major exporters has been increasing faster than world demand for it. This production increase has been due mainly to increased yields and has been most predominant in Australia and the United States (table 3). Also, the USSR and East Europe are expected to considerably reduce wheat imports because there have been substantial production improvements in the USSR grain economy. Since the early 1960s, the Russian grain harvest has climbed from an average of 130 million tonnes to over 200 million tonnes in the mid-1970s. Also, the development of high-yielding varieties of both rice and wheat in the less developed countries as part of the "Green Revolution" has reduced their potential demand for wheat.

It has been argued above that the wheat market is a buyer's market and that the major importers impose close to an optimal tariff on wheat. However, because the world does experience periodical food grain shortages, this argument is not entirely robust over time. For example, during the 1973–74 commodity boom, the market power obviously reverted to the sellers, and the optimal import tariff argument had less validity. However, even though the degree of power the importers yield may change from year to year, in general, they tend to determine world wheat prices.

Alaouze, Watson, and Sturgess suggest that surplus carryover stocks serve to maintain market shares in the exporters' triopoly. It is suggested further that the stocks provide market power for the exporters. We are somewhat skeptical of this latter suggestion and believe that stocks do not necessarily detract from the market power of the importers, especially when stocks are "excessive," as is often the case. Stockholding on the part of exporters is usually not used for optimal export pricing but, rather, is a result of excess supply. They are seldom used as a weapon against importers! If they were, importers could also hold stocks to offset any market power exporters may have (see Feder, Just, and Schmitz). In most years it appears that the cost of holding stocks is borne by exporters, not importers.

Table 3. Wheat: Average Production, 1954–55 to 1976–77

	1954–55 to 1958–59	1964–65 to 1968–69	1974–75 to 1976–77[a]
	------ 1,000 metric tons ------		
Canada	12,057	18,160	18,403
United States	29,064	38,337	54,925
Argentina	6,514	7,278	7,685
Australia and New Zealand	4,521	10,787	11,489

Source: International Wheat Council.
[a] 1976–77 data are provisional.

Conclusion

This paper has emphasized, using a rather naive model, that market power on the part of importers of wheat is perhaps greater than the power attributed to exporters by previous researchers. If this is true, price formation on the world wheat market may rest largely in the hands of wheat importers. However, because of the importance of this topic and because the structure of the wheat market is more complex than depicted in this paper, further research is needed to integrate the role of both exporters and importers in price formation. Also, in this paper only, consumers, producers, and governments were considered. To make a structural model of the world wheat market complete, market intermediaries (e.g., Canadian Wheat Board and Cargill) should also be included. One approach might follow a model recently developed by Just, Schmitz, and Zilberman, where intermediaries are assigned different objective functions.

The arguments presented in this paper are directly related to recent and ongoing discussions on the feasibility of exporters forming a cartel in wheat. If, as hypothesized by others, exporting nations currently have market power, a major question (left unaddressed by the literature) is whether or not these exporters can use their power optimally in the form of an "optimal export tax." However, in view of our discussion above, it appears that the cartel argument runs the other way. That is, the wheat exporting nations may want to form an export cartel, but the most they can hope for is a removal of the buying power of importers and perhaps a movement closer to the free-trade solution (from the direction of the optimum import tax solution). The task of the exporters setting the optimal export tax (cartel solution) is a difficult and perhaps impossible one.

[Received September 1978; revision accepted February 1979.]

References

Alaouze, C. M., A. S. Watson, and N. H. Sturgess. "Oligopoly Pricing in the World Wheat Market." *Amer. J. Agr. Econ.* 60(1978):173–85.

Cline, W. R., N. Kawanabe, T. O. M. Kronsjö, and T.

Williams. *Trade Negotiations in the Tokyo Round: A Quantitative Assessment.* Washington, D.C.: The Brookings Institution, 1978.

Enke, S. "The Monopsony Case for Tariffs." *Quart. J. Econ.* 58(1944):229–45.

Feder, G., R. Just, and A. Schmitz. "Storage with Price Uncertainty in International Trade." *Int. Econ. Rev.* 18(1977):553–68.

International Wheat Council. *World Wheat Statistics, 1966.* London: Bradleys, Reading, and London, 1966, and subsequent annual issues.

Johnson, D. G. "The Impact of Freer Trade on North American Agriculture." *Amer. J. Agr. Econ.* 55(1973):294–300.

Just, R. E., A. Schmitz, and D. Zilberman. "Price Controls and Optimal Export Policies under Alternative Market Structures." *Amer. Econ. Rev.*, in press.

McCalla, A. F. "A Duopoly Model of World Wheat Pricing." *J. Farm Econ.* 48(1966):711–27.

Riesenfeld, S. A. "Common Market for Agricultural Products and Common Agricultural Policy in the European Economic Community." *International Trade, Investment, and Organization*, ed. W. R. LaFave and P. Hay. Urbana: University of Illinois Press, 1967.

Scherer, F. M. *Industrial Market Structure and Economic Performance.* Chicago, Ill.: Rand-McNally & Co., 1973.

Schmitz, A., and L. Bawden. *The World Wheat Economy: An Empirical Analysis.* Giannini Foundation Monograph No. 32, University of California, Berkeley, 1973.

Taplin, J. H. "Demand in the World Wheat Market and the Export Policies of the United States, Canada and Australia." Ph.D. thesis, Cornell University, 1969.

The Economist, 11 Nov. 1978, p. 88.

U.S. Department of Agriculture. *World Demand Prospects for Grain in 1980 with Emphasis on Trade by the Less Developed Countries.* ERS. For. Agr. Econ. Rep. 75, 1971.

———. *Wheat Situation.* ESCS WS-243, Feb. 1978, and various issues.

Capital-Surplus, Labor-Short Economies: Yemen as a Challenge to Rural Development Strategies

John M. Cohen and David B. Lewis

If the test of a development model is its capacity to yield strategies that deal effectively with new and different situations, then the Yemen Arab Republic will be a good proving ground for contemporary theoretical approaches to agricultural and rural development. Until the early 1970s Yemen's annual gross national income was less than US$100 per capita; the country had a shortage of capital and a surplus of labor—characteristics shared by many developing countries. Within the last five years, however, employment opportunities in Saudi Arabia have attracted some 40% of Yemen's male labor force, and the remittance of earnings by these workers has increased Yemen's gross national income per capita by a factor of six. Policy makers now face the problem of planning for national development under conditions of capital surplus and labor shortage. There is a growing concern that the dominant models of agricultural and rural development cannot generate strategies responsive to their needs.

Paradigms and Anomalies

In any science at a given point in time, there is generally a fundamental image defining the agenda of topics to be studied, the concepts used in inquiry, the validity of propositions that emerge, the essential elements of the model or framework that integrates them, and appropriateness of policy actions based on the accumulated research (Kuhn). Such an image constitutes a paradigm. Typically, while science operates within the paradigm, forward thinking scientists explore its boundaries and seek to expand it. This effort inevitably uncovers anomalies which cannot be explained or dealt with by the dominant perspective. These problems lead supporters of the paradigm to develop it further so that the anomalies can be resolved. If anomalies grow in number and remain intransigently unresolvable, a crisis is reached. Usually this results in the emergence of a new paradigm.

The work of Johnston and Kilby, Mellor and Lele, and others has been fundamental in defining what is today a major paradigm in international agricultural economics and the conceptual basis for much of the contemporary work on rural development strategies. The question we wish to raise is whether the problems of rural-based, capital-surplus, and labor-short economies constitute an anomaly to this general perspective. Specifically, we propose to describe the interesting case of the Yemen Arab Republic, in order to alert rural development specialists to a situation which appears to be an anomaly needing additional theoretical work. We hope this research note will lead agricultural economists to a particularly careful study of countries like Yemen, because we believe that the focus on such unique cases may lead to significant improvements in development theory and strategy.

Rural Development Paradigm

Since the mid-1960s, a new strategy of rural development has emerged. Increasingly national leaders, policy makers, and development experts are looking beyond the industry-led, capital investment-based strategy that dominated development theory during the first two decades of the post World War II era (Johnston and Mellor, Mellor, Johnston and Kilby, Hunter, Owens and Shaw). Growing attention is being devoted to rural development with efforts concentrated not only on increasing food production to accommodate population growth, but also on improving income levels of rural inhabitants—the majority of the population in many countries. This increase in income for a substantial portion of the population is expected to generate increased demand for domestic industrial products (Mellor and Lele). Past experience suggests that increasing agricultural output and improving income distribution in the rural sector may be the only effective way to stimulate sustained development.

The shift toward rural-led development strategies was accelerated by the appearance of high-yielding varieties of wheat, rice, and corn (Brown, Streeter). When combined with fertilizer, water, and the proper production practices under favorable conditions, these hybrids typically yield more than traditional varieties. The technology of the new high-yielding varieties has been effectively used on both

---

John M. Cohen is a rural sociologist and institute fellow at the Harvard Institute for International Development. David B. Lewis is an economist and assistant professor in Cornell University's Department of City and Regional Planning.

Work from which this note was developed was funded under a cooperative agreement between Cornell University's Rural Development Committee and the Office of Rural Development of USAID focused on "Rural Development Participation."

large and small holdings. After initial experiences with the tendency of large farmers to adopt capital-intensive, labor-displacing practices, however, many governments and international agencies now seek to raise yields through small farm strategies. The choice has been made easier by the increasing evidence that small farms can be as productive with food crops and some nonfoods as the larger-scale commercial farms. For example, the highest yields of food grains per land unit in the world are found on small-scale holdings in Taiwan, South Korea, China, and Japan (Owen, pp. 31–6).

The effectiveness of small farm policies depends on the development and maintenance of a progressive rural structure (Mosher). This includes elements such as agricultural research and production incentives that are effective in serving the needs of the small farmers; commercial centers through which farmers can obtain supplies and sell their production output; rural roads to increase flows of supplies, goods, information and services; extension activities; credit facilities; group action by farmers, and so on. Much of the growth of a progressive rural structure is a private sector response to the stimuli resulting from increased rural income, but the government must also follow land, tax, pricing and monetary policies supportive of economic growth with equity.

Until the mid-1970s this small-scale farm strategy seemed to fit the needs of the Yemen Arab Republic. Its physical, social, economic and political characteristics were compatible with the basic assumptions underlying the new agriculture-led development model. However, because of some very unusual economic events the comprehensiveness of the model in general, and its appropriateness for Yemen in particular, now seem challenged.

Rural Economy of Yemen Arab Republic

Yemen is located at the southern corner of the Arabian peninsula. Aside from some general introductions (Wenner; Nyrop; Stookey; Tutwiler, Murdock and Horowitz; economic details and a summary of the rural economy can be found in Cohen and Lewis) little information is available on the country or its development opportunities and problems. It is composed of areas that vary greatly with regard to their ecological, agricultural, and societal characteristics, ranging from the dry but productive coastal lowlands of the Tihama, through the agriculturally rich waddis of foothills and fertile highlands bordered by rugged mountain peaks, to the arid deserts of the interior of the peninsula. For centuries this Islamic country was a nominal dependency of the Ottoman Empire. After gaining independence at the end of the First World War, it was ruled by an Iman who kept the country largely isolated from the West and closed to external economic forces and technological innovations. This absolutism ended in 1962 with a coup that only partially succeeded. For the next several years, civil war between nationalistic republican army officers and royalists prevented much development progress in rural or urban areas. By 1969 the republicans gained the dominant position and the war ended. Attempted coups d'etat, assassinations of top political leaders, and tribal conflict, however, have continued to threaten national stability. Even today, the central government has only limited authority in the hinterland. The functions of local government are performed largely by the village sheikhs—traditionally independent men for whom tribal allegiances are often paramount to national concerns. While the larger towns and southern and western parts of the country are more integrated with the national government, few government officials go into the remoter regions of the north without apprehension.

On the basis of data from the early 1970s, we know that Yemen has some six million people and an area of 145,000 square kilometers. Nearly 90% of the population traditionally has earned its livelihood from agriculture or animal husbandry. The rural sector is divided into highland, waddi, coastal plain, and arid regions. The major crops of the highlands are sorghum, wheat, millet, barley, fruits, tomatoes, potatoes, and a variety of lentils. The seasonally heavy flowing rivers of the foothill waddis permit the cultivation of most cereals, corn, sugar cane, and tropical fruits such as mangoes or bananas. Dates, tobacco, cotton, millet, and sorghum are widely grown on the hot Tihama plain along the coast. Most farmers also raise a large variety of livestock, and pastoralists work their herds on the arid fringes of the cultivated areas.

Overall, some 90% of agricultural crop production is made up of cereals, with the northern parts of the country dominated by sorghum, millet, and barley, and the south by sorghum and maize. A total of some 1.8 million hectares are thought to be in production. In 1972 agriculture accounted for 70% of gross national product, with coffee being the major export product, followed by cotton, salt, and hides. Despite this well-established agrarian base, by 1970, food production was lagging behind population growth. The problem has since been exacerbated by recurring periods of drought.

Most rural people live on small farms using traditional production techniques and working the soil either by hand or with oxen. Rural land ownership patterns vary from region to region, but the country does not seem to be plagued by the kinds of concentrated holdings that make rural development difficult in countries like the Philippines. While irrigation has increased since the end of the civil war, most farmers are still limited to dry farming practices. They have, however, developed a high degree of sophistication in the management of runoff rain water. On the terraced hillsides and in the waddis, it is efficiently channeled from field to field with minimal losses.

In 1972 industry accounted for only 3% of Yemen's gross domestic product, and it employed less than 1% of the labor force. Despite a 1969 law designed to attract foreign capital investment, the country still has only one textile mill, a small aluminum plant, and a cement factory—all representing foreign aid. The use of mechanical power is limited. The country has no known oil, and other mineral resources are both limited and largely untapped. Aside from agriculture, the country's greatest asset is its manpower. Yemen historically has supplemented income from domestic production with income earned and repatriated by its emigrants working abroad.

In 1972 the country stood at the bottom of most lists for demographic, development and quality of life indicators. Per capita income was US$80 per year, illiteracy rates ran more than 90%, and such pervasive diseases as tuberculosis and malaria, as well as chronic malnutrition, kept life expectancy at the low level of thirty-six years. Few public services reached the towns, much less the villages, and amenities such as potable water systems, health clinics, or schools were available only in a few of the larger towns. Sanitary public sewers were unknown in most towns and paved streets rare. Moreover, there was an acute shortage of trained manpower to staff clinics, schools, or public welfare organizations. Indeed, the government had few of the technical or middle-level managerial people so necessary to get development moving. And, in the agricultural sector, there was little agricultural research, no production credit programs, and few extension agents. Poor road and communication networks held back the development of efficient markets and storage systems were scarcely developed.

Despite this dismal description, the situation is changing and Yemen has the potential for a productive and profitable rural sector. The country contains some of the most fertile land on the Arabian Peninsula and its people are hard working, energetic, and entrepreneurial. Moreover, the ruling military coalition has a political and economic philosophy centered on Islam, pragmatism, and free enterprise.

Given the situation in Yemen in the early 1970s, the policy prescriptions of the new rural development model (described earlier) would seem to be as appropriate as for such countries as Ethiopia, Kenya, Bangladesh, Peru, or Indonesia. However, the rapid increase in employment opportunities in Saudi Arabia has changed two critical characteristics of the situation in Yemen: capital is relatively more abundant and labor is in short supply.

The Changing Context in Yemen

Information on recent change in Yemen is difficult to acquire, though some helpful reports exist (Ross, Keyser, UNCWA). These indicate that the increased demand for labor in Saudi Arabia has attracted some 600,000 males from Yemen, roughly 40% of the labor force. Most are unskilled when they emigrate, but they typically earn wages four times the presently prevailing levels in Yemen. The 1977 remittances from these workers totaled US$ 1.5 billion. This inflow of funds has caused annual per capita income to increase from US$80 before the oil boom to present levels of more than US$ 500. The money supply in Yemen has increased by a factor of more than twelve since 1972. Incredibly, more than two-thirds of this money supply is held outside the formal banking system in the form of currency.

Yemen's change in fortunes is a direct result of the development boom in Saudi Arabia. Yemeni political leaders and policy makers are concerned, however, with how long the current situation will last. Yemen enjoys a special relationship with Saudi Arabia, but workers from other Islamic countries do represent an increasingly important alternative and competitive source of labor. Also the pace of construction, a key factor in current levels of labor demand, may slacken as Saudi Arabia completes its current phase of development. Finally, a change in the world energy supply structure or in relations between Saudi Arabia and Yemen could bring abrupt changes in employment opportunities for Yemenis.

Opinion varies greatly, but the consensus suggests it would be dangerous for Yemen to assume that it can count on its currently extraordinary remittances for more than twenty years. Indeed, the unpredictable politics of the Middle East could cut it off much sooner than most observers predict. Hence, it seems reasonable to suggest that Yemen view itself as being in a grace period, and use the time and resources to build rural institutions and infrastructure in anticipation of the day the migration opportunities decline.

The effects of these sudden changes are visible throughout Yemen. Migration is moving more women into agricultural roles and bringing new skills and resources back into the country. Structural changes are occurring in local transportation systems, consumption patterns, market prices, and foreign trade. New local or village level development associations have appeared which might be able to channel some of the new wealth into rural development projects. Unfortunately for policy makers seeking to devise strategies for rural development, there is little data available on the nature or trend of such changes.

Yemen: A Challenge to the Paradigm?

The theoretical guidelines proven useful in other poor, rural-based countries are not particularly helpful in the Yemen context. There are two main elements to this problem. First, although the country has agricultural potential, no progressive rural

structure, and potentially productive small-scale farms, the capital surplus/labor shortage situation appears to fall outside the accepted assumptions of the paradigm. Second, some of the functional relationships implied by the strategy do not seem to be borne out by the experience of Yemen over the last few years.

Assumptions

The model of Johnston, Mellor, and others generally assumes that rural families have low incomes and that rural poverty is a major problem. The rural population in Yemen, while not necessarily affluent, does not fit the assumption very well. By contrast with many developing countries, this increase in gross national income has been distributed rather equitably among the population. Coming primarily from the export of labor in the form of earnings of individual emigrants, the incomes do not appear to have been concentrated in the hands of owners of capital or land. The typical pattern seems to be for a family to release one son to go to Saudi Arabia. He works there for one or two years, sending home remittances regularly. He then returns, usually bringing appliances and consumer goods with him. While he is away, his brothers, and in some cases his wife, will look after the family's agricultural interests and activities. Commonly, as one brother returns another migrates—again for one or two years of work in Saudi Arabia.

The effect of this migration pattern and the associated remittances has been to place resources in the hands of a widely spread rural population. The government does not tax these remittances, and, hence, has very limited funds of its own. In contrast with other developing countries, the rural population is the principal holder of the liquid financial resources needed for development. With more than two-thirds of the money supply being privately held outside of the formal financial system of the country, the government has relatively little direct control over its allocation and expenditure. This puts the government in a substantially different position from its counterparts in other developing countries, where the discretionary financial resources are concentrated in the hands of the administration.

Another discrepancy between the assumptions of the general model and the situation in Yemen is that the rural labor force does have an opportunity for obtaining high-paying employment. Limited data suggest there is relatively low unemployment in the rural areas for reasons other than the "self-absorptive" ability of rural economies. This phenomenon varies from one region to another depending on the degree of emigration, but it is sufficiently widespread that individuals rarely have to accept unemployment involuntarily. The informal network for sending laborers to Saudi Arabia and placing them in employment there is well-established and apparently very effective.

As a result of the substantial remittances from abroad, the domestic economy enjoys an abundance of foreign exchange. Unlike the situation encountered in many developing countries, Yemen has a vigorous system of local commercial activity. It is virtually unconstrained by either high duties on imports or shortages of foreign exchange. Residents of local towns are served by stores featuring the latest in imported Japanese stereo tape cassette players and cameras. They can also buy four-wheel drive tractors from France and canned food from Eastern Europe. It should be noted that the network is primarily commercial in nature, and relatively undeveloped in terms of being able to service the products it sells or helping the consumer select equipment appropriate to his needs. This is particularly true in the area of agriculture machinery. Establishments selling tractors, for example, are often not in a position to advise customers on the appropriate selection of implements to be used with the tractor, nor are they organized to supply spare parts on a regular basis.

There seems to be minimal pressure on agricultural land. The Tihama region is under-utilized, with big sections lying vacant. In other areas, agricultural land is going out of use as rural people redirect their labor toward employment in Saudi Arabia. It should be noted that the lands falling into disuse tend to be of marginal quality. They often, however, represent a substantial past investment of capital in that they are, typically, terraced fields, and when neglected for several years, the supporting walls often deteriorate to the point that the terraces collapse and the top soil is washed away by the rain. Another perhaps even more significant indicator of the decreasing pressure on agriculture land is the shift of its use from essential food crops into luxury crops. This is especially true of *qat,* a mildly narcotic plant whose leaves are chewed to produce a sense of euphoria and alertness in the chewer. With the growing per capita income, people can now afford to import more food, grow less at home, and use the land to grow *qat*—an important element to the culture, but not nutritionally essential to life.

Finally, Yemen has an interesting system of local or village level development associations (Green). These are supported primarily by their local constituencies and undertake, in some cases, significant development projects, such as roads and water systems. In addition, there is increasing evidence that rural areas can mobilize marketing and production cooperatives that are successful. For example, the agricultural Cooperative Society of Al-Lawiah in the Tihama has in two years initiated a share-capital enterprise that supplies agricultural inputs to the community, owns a gas station, owns and rents a bulldozer for land reclamation, and markets substantial quantities of okra in Saudia Arabia (Gow). As information emerges on the rural sector, it becomes increasingly clear that local communities have shrewd, intelligent leaders, progressive community members, and a general instinct

for profitable rural development activities. The major question is what kinds of policies the government should follow to capitalize on this potential? Answering this question appears to raise difficult theoretical issues.

Functional Relationships

In effect, it appears that the remittances from abroad are a temporary but functional substitute for the increased income of Johnston and Mellor's highly productive small-scale farmers. Small towns are thriving commercially and a large percentage of the population has resources to spend on capital and consumer goods. The rural development strategy, however, is largely dependent on the viability of the small farm—the capacity of the small farmer to support himself through his efforts on his own land. Given the current price structure for imported food, the farmer in Yemen has difficulty competing. Imported food grains can be sold at a lower cost than those produced domestically. A typical store in the capital city will have frozen chickens imported from France selling at a lower price than domestic chickens. It is common to see fruit imported from the United States selling in rural areas.

The government would like to stimulate the development of institutions and infrastructure that would support development of the rural sector, but with the exception of requests for roads and water systems and occasionally a school or clinic, there is relatively little spontaneous demand. With the purchasing power that exists in the rural sector, there has been relatively little demand, for example, for agricultural credit. And the government has done little to mobilize rural savings. Similarly, there seems to be relatively little elasticity in the demand for traditional crops such as sorghum and millet. Families customarily produce only for their own needs, and government efforts to increase the output of these cereals have been only marginally effective.

The central tenet of the rural development paradigm tested here is the importance of increasing the income of the small farmer. In Yemen a significant proportion of the rural population already has substantially more money than it has ever had before. The rural commercial and manufacturing systems, however, do not seem to be serving the needs of a progressive rural structure. There does not appear to be a growing demand for locally produced agriculture implements, and there does not appear to be a supply of these implements which might stimulate a demand. A very sophisticated and effective marketing system has emerged for *qat*, and it demonstrates a capability for efficient economic response. Despite attractive price differentials, this type of response has not been widely duplicated, however, for other agricultural commodities. A box of tomatoes, which sells for 10 riyals (one riyal = US$0.21) at the farm gate, sells for 55 in a city less than two hours drive away.

In sum, one is left with a concern that although rural development is badly needed in Yemen, the contemporary model may not be helpful in offering effective policies or strategies. Many of the concerns of the model are already being addressed—people have a substantial increase in income; yet, the private sector element of a progressive rural structure which should be emerging has not begun to materialize. In this regard a fundamental question is how can the basic small-farm strategy be modified to create a modernizing agriculture that will be viable when out migration and high remittance levels are no longer possible and the economy has to rest on its potentially productive agrarian sector?

[Received July 1978; revision accepted December 1978.]

References

Brown, Lester R. *Seeds of Change: The Green Revolution and Development in the 1970s.* New York: Praeger Publishers, 1970.

Cohen, John M., and David B. Lewis. "Rural Development in the Yemen Arab Republic." Harvard Institute for International Development Disc. Pap. No. 52, Harvard University, Feb. 1979.

Gow, David. "Narrative Case Study of the Agricultural Cooperative Society of Al-Lawiah, Yemen." Preliminary Report, Development Alternatives Inc., Washington, D.C., 1978.

Green, James Wyche. *Local Initiative in Yemen: Studies of Four Local Development Associations.* Washington, D.C.: United States Agency for International Development, Oct. 1975.

Hunter, Guy. *The Modernization of Peasant Societies.* New York: Oxford University Press, 1967.

International Bank for Reconstruction and Development. "Agricultural Sector Memorandum for Yemen Arab Republic." Draft Memo., 14 April 1977.

Johnston, Bruce, and Peter Kilby. *Agriculture and Structural Transformation: Economic Strategies in Late-Developing Countries.* New York: Oxford University Press, 1975.

Johnston, Bruce F., and John W. Mellor. "The Role of Agriculture in Economic Development." *Amer. Econ. Rev.* 51(1961):565–93.

Keyser, James. "Trip Report—Yemen." U.S. Agency for International Development, Internal Memo., Washington, D.C., 14 Mar. 1977.

Kuhn, Thomas. *The Structure of Scientific Revolutions.* Chicago: University of Chicago Press, 1962.

Mellor, John W. *The Economics of Agricultural Development.* Ithaca: Cornell University Press, 1966.

Mellor, John W., and Uma J. Lele. "Growth Linkages of the New Food Grain Technologies." *Indian J. Agr. Econ.* 28(1973):35–55.

Mosher, A. T. *Creating a Progressive Rural Structure: To Serve a Modern Agriculture.* New York: Agricultural Development Council, 1969.

Nyrop, Richard F. *Area Handbook for the Yemens.*

Washington, D.C.: Government Printing Office, 1977.

Owen, Wyn F. "The Significance of Small Farms in Developing Countries." *Small Farm Agricultural Development Problems.*, ed. Huntly H. Biggs and Ronald L. Tinnermeier. Fort Collins: Colorado State University, 1974.

Owens, Edgar, and Robert Shaw. *Development Reconsidered.* Lexington, Mass.: D.C. Heath Co., 1972.

Ross, Lee Ann. "Yemen Migration—Blessing and Dilemma." Paper presented to USAID Seminar on Near East Labor Flows, Washington, D.C., 1977.

Stookey, Robert W. "Social Structure and Politics in the Yemen Arab Republic." *Middle East J.* 28(1974):248–60; 409–18.

Streeter, Carroll P. *Reaching the Developing World's Small Farmers.* New York: Rockefeller Foundation, 1975.

Tutwiler, Richard N., Muneera Salem Murdock, and Michael M. Horowitz. *Workshop on the Problems and Prospects for Development in the Yemen Arab Republic: The Contribution of the Social Sciences.* Binghampton: Institute for Development Anthropology Rep. No. 2, 1976.

Wenner, Manfred. *Modern Yemen, 1918–1966.* Baltimore: Johns Hopkins University Press, 1967.

United Nations Commission for Western Asia. "Summary of the First Five-Year Plan of the Yemen Arab Republic." Draft Summary, UNCWA, Beirut, Nov. 1977.

The Effect of Water Quality on Rural Nonfarm Residential Property Values

Donald J. Epp and K. S. Al-Ani

The past decade has seen a phenomenal increase in public awareness and concern over environmental quality. The desire to consume larger amounts of environmental quality has been difficult to satisfy because many of the natural resources involved do not lend themselves to market allocation. This failure of markets to solve the major environmental quality problems has been well documented (Bator, Mishan, Samuelson, Turvey), and generally can be attributed to externalities imposed by use of the environment and the public goods nature of many natural resources.

The failure of markets to perform the allocation function to the satisfaction of most people has caused us to turn to other institutions for solutions. Most frequently society has turned to legal processes, both the passage of new legislation and the interpretation or enforcement of existing legislation in the courts. While these activities affect many environmental areas, this paper is focused on water quality, where many state and federal laws have been passed in recent years. Typical of this legislative effort are the 1972 Amendments to the Water Pollution Control Act (P.L. 92-500) and the 1977 Clean Water Act (P.L. 95-217). These acts specify national goals and policies to eliminate the discharge of pollutants into surface waters, encourage policies that maintain a level of water quality sufficient to protect fish and wildlife, require local authorities to establish waste treatment projects, and finance the development of pollution abatement technology.

While there has been political support for these laws, economic analyses of their effects have concentrated largely on determining the costs of achieving the standards set through the political process (e.g., Nagadevara, Heady, Nicol; Pound, Crites, Griffes; Van Note, Hebert, Patel; Young). Very little evidence has been presented that measures the demand (in the economic sense) for environmental quality in general or water quality specifically. This article reports an attempt to determine one aspect of the demand for one kind of environmental quality—clean streams.

The study reported here used real estate prices to determine value of improvements in water quality in small rivers and streams in Pennsylvania. The specific objectives of the study were (*a*) to estimate the relationship between water quality and the value of residential properties adjacent to small rivers and streams; and (*b*) to estimate the effect of various components of water quality, such as acidity, dissolved oxygen, biochemical oxygen demand, and nitrate and phosphate levels, on the value of properties adjacent to small streams.

The second objective was included because various pollutants have different physical and biological effects in the streams, have very different costs for removing marginal increments, and usually are listed separately in quality standards established for specific streams.

The Model

Traditionally, the real estate market consists of at least four parts—residential, commercial, industrial, and agricultural—each of which may be divided into a market for rental of services and a market for purchase of stocks. The model developed in this study concentrates on the market for the purchase of housing stocks, but does not use the conventional supply and demand approach. Due to the wide variety of housing characteristics provided by units on the market at any one time, especially in the rural areas of particular interest to this study, it is inappropriate to represent these markets with a model that assumes homogenous products. Instead, a hedonic model based on property characteristics is developed. Using such a model, the economic analyst can determine the implicit price of various attributes of properties from observed prices of differential products and the specific amount of each attribute associated with them (Rosen, p. 34).

For this study, the characteristics of residential property are divided into four groups and related to market value as

$$V = f(\Sigma R_j, \Sigma S_j, \Sigma T_j, \Sigma U_j),$$

where V is the market value of the property; R_j is the value of physical housing characteristic j, such as number of rooms or age of the house; S_j is the value of neighborhood characteristic j, such as

Donald J. Epp is an associate professor of agricultural economics at Pennsylvania State University and K. S. Al-Ani is head of the Department of Cooperatives and Farm Management, University of Baghdad, Iraq.

Authorized for publication as paper 5545 in the journal series of the Pennsylvania Agricultural Experiment Station. The authors gratefully acknowledge the helpful comments of Walter Haessel and C. Edwin Young.

community average income, average education level, or employment rate; T_j is the value of accessibility characteristic j, such as distance to major highways, to a metropolitan area, or to a waterway; and U_j is the value of amenity characteristic j, such as water quality or topography (Al-Ani).

Estimating the Model

Small rivers and streams in Pennsylvania (average discharge of 850 cubic feet per second or less) with documented levels of various water quality components were classified as clean if all components were within the normal range established for surface waters by the National Academy of Science and polluted if one or more components had levels outside the normal range. A paired sample, consisting of twelve clean streams which had not undergone recent quality improvement and thirteen polluted streams, was selected. On each stream a site was selected to consist mainly of rural, nonfarm, small communities located away from the suburbanizing influence of large cities. It was required that each site be located along the stream and within two stream miles of a Pennsylvania water quality network stream station (Pennsylvania Department of Environmental Resources).

Data on properties containing one single-family, owner-occupied dwelling, ownership of which was transferred between 1969 and 1976, were collected for these sites from public records and from telephone interviews with present property owners. Only properties occupied by the owner year-round and located within 700 feet of the stream were included in the study.

The sampling procedure was designed to isolate the influence of water quality on property value by minimizing the variability between properties of characteristics other than water quality. Similarly, a comparison across streams rather than a time-series was used to minimize the impact of changes in value that occur over time. An additional advantage of the across-stream comparison is that it gives a greater variation in water quality characteristics. Time-series data on streams that have experienced significant changes in water quality are very limited.

Specification of the Variables

The dependent variable, property value, was measured using actual sale price and excluded invalid transactions, such as sales to relatives and nominal sale prices. Sale prices were deflated to the base year 1972 using the quarterly implicit price deflators of residential nonfarm structures (U.S. Department of Commerce).

The independent variables are of two kinds, those that vary for each property and those that vary between sites but which have identical values for all properties within a site. All of the independent variables used in this study are shown in table 1 along with an indication of whether the variation is by site or individual property, the unit of measurement, and the a priori expectation of direction of effect.

The selection of the components of water quality to be included in the model was based upon their possible effects on nonconsumptive uses of the stream, primarily recreation or aesthetic appreciation. Several specific components of water quality were tried in this study—pH, dissolved oxygen, biochemical oxygen demand, acid from minerals, acid from carbon dioxide, and nitrate and phosphate concentrations. Only the three measures of acidity had consistently significant effects on property values. Acidity from minerals, acidity from carbon dioxide, and pH each had similar effects on property value when entered as the single measure of water quality. Because pH is the more widely used measure of acidity in water, it was used throughout the rest of the analysis. For some purposes, pH was transformed into a dummy variable equal to zero if pH was 5.5 or lower, otherwise equal to one. The pH of 5.5 was chosen for this purpose because water with a pH of less than 5.5 has severe limitations for recreational use.

A general measure of water quality was based on the perceptions of the property owners as determined in the survey. If the owner indicated a belief that the stream had a water quality problem and that this prevented his using the stream for a specific recreational or aesthetic activity, the value of zero was assigned to the variable. In this way, perceptions of water quality, whether factual or not, could be entered into the analysis.

The hazard of flooding was determined from interviews with present homeowners. Responses to the question about frequency of flooding were converted to probabilities ranging from zero if the property never flooded to 0.99 if the property was flooded annually.

Lots in rural communities may vary greatly in size, being as small as one-fifth of an acre to as large as several acres. In this study, lot size was calculated to the hundreth of an acre.

The opportunity to find employment nearby is an important consideration in choosing a residence and is hypothesized to be positively related to sale price. An index of potential employment (*PER*) was constructed using a gravity model to weight actual numbers of employed individuals by distance using the following equation.[1]

$$PER_i = \sum_{j=1}^{n} D_{ij}^2 + 1$$

where PER_i is potential employment by residence

[1] The authors acknowledge the assistance of Frank M. Goode in developing the final form of the equation and in providing access to data for calculating *PER* values.

Table 1. Single Equation Estimates of the Effect of Selected Variables on the Value of Residential Properties

Variable and Level of Observation (P = property, S = site)	Units	Expected Sign	Mean Values	Coefficient Values	
				Model 1	Model 2
pH (S)	pH units	+	5.694	.344* (.130)	
Interaction of pH_D and percentage change in population, 1960–70	%	+		.115* (.023)	
Perceived water quality (P)	0,1	+			.246* (.055)
Interaction of perceived water quality and percentage change in population, 1960–70	%	+			.129* (.022)
Flood hazard (P)	Probability	–	.063	−.568* (.176)	−.491* (.171)
Lot size (P)	acre	+	.917	.349* (.088)	.317* (.086)
Number of rooms (P)	number	+	9.085	.604* (.109)	.586* (.106)
Potential employment (S)	number of jobs	+	1090.052	.160* (.027)	.133* (.025)
Per pupil expenditure (S)	$	+	1007.100	1.861* (.435)	2.180* (.404)
Percentage change in population, 1960–70 (S)	%	+	.548	−.001 (.015)	−.002 (.015)
Age of house (10–24) (P)	0,1	–	.156	−.274 (.174)	−.273 (.169)
Age of house (25–49) (P)	0,1	–	.264	−.516* (.172)	−.526* (.165)
Age of house (50 and over) (P)	0,1	+ or –	.557	−.847* (.170)	−.822* (.164)
Income (>$10,000 = 1) ($P$)	0,1	+	.590	−.197* (.053)	−.169* (.052)
Constant				−6.449	−7.841
$\bar{R}^2$				.67	.69
N				212	212

Note: Standard errors in parentheses. Asterisk denotes coefficient was significant at the 1% level.

at site i; E_j is employment at the jth minor civil division (MCD) within a 20-mile radius of site i, including the MCD containing site i; and D_{ij} is distance (in miles) from the center of site i to the center of MCD_j.

Another important factor in choosing a residence is the level of services provided by local government and schools. School expenditures per pupil (annual operating budget divided by average daily enrollent) was selected as the measure of school services. Expenditure per pupil was chosen over school tax rate because state aid payments to school districts vary greatly. It is believed expenditures more accurately reflect school quality in this case than do local tax revenues. The real estate tax rate for schools and local government combined also was tried as an independent variable but did not improve the model.

The dummy variable for age of the house over fifty years is of uncertain effect on property value. In some localities in Pennsylvania, very old houses have added value as antique or historic properties. Thus, the expected effect is indeterminate.

Income in this study is reported individual family income. To increase response, the income question in the survey was worded to determine which of five income categories contained the family annual income. Thus, income was treated as a dummy variable. Several specifications were tried and a qualitative variable form with $10,000 as the dividing point was chosen. Contrary to previous studies, this study did not use median income as a proxy for housing quality but, rather, measured housing quality directly.

Several variables were considered in addition to the variables used in the final specifications of the model. Characteristics of the house and neighborhood included the age of the house as a continuous variable and the size of the stream measured by average annual flow. Accessibility characteristics

considered included the distance to a major highway, the distance from the property to the waterway, and the ease of access to the waterway indicated by a dummy variable which took the value of one if there was a building, hill, or other obstruction between the stream and the property being studied. None of these variables increased the explanatory ability of the models when added to those shown in table 1 or substituted for similar variables.

Empirical Estimates

Estimation of the model was conducted in two ways. First, all 212 property observations were combined into one pooled-data set to estimate the parameters of various forms of the equation. A second estimate of the effect of water quality on property value made use of the fact that the sample was taken in part from streams of good water quality and in part from polluted streams. The second, or paired sample, approach estimated the parameters of the equation twice, once with data from clean stream sites and once with data from polluted stream sites.

The logarithms of the dependent variable (property sale price) and the continuous independent variables were used in estimating the parameters of the equation. Other functional forms were considered. The linear, semilogarithm and inverse semilogrithmic forms were rejected because of greater hetroscedasticity and because coefficients of the selected form are more easily given economic meaning. The analysis also specifically considered the potential problems caused by multicollinearity among independent variables. Initial screening of the variables using the Klein test (Klein, p. 101) did not indicate any potential problem. Preliminary runs of the paired-sample approach seemed to indicate, however, that three variables had an interaction with water quality. These were the number of rooms, the percentage change in population, and the dummy variable representing houses between ten and twenty-four years old. Interaction terms between water quality and the three variables listed were constructed and tested. Only the interaction term between water quality and the percentage change in population was found to be significant and added to the explanatory power of the equation (Al-Ani, chap 5).

Pooled sample results. The results of two different models are presented in table 1. Model 1 uses an actual measure of water quality—pH—and its interaction with the percentage change in population. Model 2, on the other hand, uses perceived water quality and its interaction with population change. All other variables are the same in both models.

The coefficients for most of the independent variables are significantly different from zero. Only two, change in population and the dummy variable denoting houses ten to twenty-four years old, were not statistically significantly different from zero at the 1% level. The lack of significance of the change in population variable probably can be attributed to the presence of the interaction variable with water quality. It is likely that population change effects are picked up by that variable. The age of the house apparently is not significant for houses less than twenty-five years old. Houses more than twenty-five years old are, however, sold at significantly lower prices.

The second observation of importance for this study is that all of the variables reflecting conditions in the natural environment (water quality and flood hazard) are significant. Water quality, whether measured by pH or by the owners' perceptions, has a significant effect on the price of adjacent property. Water quality has an additional impact through its interaction with the percentage change in population. That variable indicates that population growth is significantly related to property value, but only for good quality streams. Flood hazard, too, is significantly related to land price with the expected negative relationship.

The coefficient for the dummy variable income has a negative sign in model one and is statistically significantly different from zero. This is the only instance in either model where a coefficient that is statistically significantly different from zero does not have the expected sign, and the authors are unable to offer any explanation for this phenomenon.

From the analysis of single equation approaches to determining the effects of water quality on housing values, it can be concluded that buyers are aware of the environmental setting of a home and, specifically, that differences in the quality of water in nearby waterways affect the price paid for a residential property. The relationship is shown to be positive, as hypothesized.

The capitalized benefits from higher quality water to a property of average value can be calculated from the results shown in table 1. A one point increase in pH represents a 17.5% increase from the mean value of pH. Using the regression coefficient for pH from table 1, one would expect a 5.95% increase in the mean sales value of residential properties. This is equal to $653.96.

Paired sample results. In addition to measuring the effect of water quality on residential property value directly, as was done with the pooled-sample approach, it is possible to examine the effect water quality has on the magnitude and relative importance of other factors affecting price. For instance, one can hypothesize that the physical characteristics of the house (size, number of rooms, age) take on additional significance to a buyer if the package does not include a high quality stream. Because the data for this study were gathered from sites that had been stratified so as to represent clean streams and polluted streams (one or more components outside the normal range), the hypothesis about interaction between water quality variables and other variables

can be tested by separately estimating the model using data from clean streams and polluted streams.[2]

The results of the paired-sample estimation of the coefficients are presented in table 2. In general, the results support the contention that when water quality is poor other characteristics of the housing package assume greater importance. The environmental variables provide a good example. In clean streams, variation in pH level is statistically very significant and positively related to property value. On the other hand, variation in pH in polluted streams has no significant effect on property value. The flood hazard has the opposite effect. On clean streams, where the average of reported flooding probability was nearly 10%, the prospect of flooding had no statistically significant effect on price. On polluted streams, however, the flooding hazard had a significant negative impact on price, even though the average of reported flooding probabilities was one-third that of properties along clean streams. Apparently, if owners do not have the benefits of a clean stream, they are influenced by negative aspects of the stream, such as flooding.

Other characteristics appear with larger coefficients and greater significance in the estimates for polluted streams than for clean streams. The importance of expenditures on schooling is not only significant in the polluted stream estimate and non-significant for clean streams, it also is dramatically larger than other coefficients in the equation. The large coefficient indicates a great importance in the minds of buyers.

Characteristics of the house itself also take on added importance when the stream is polluted. The coefficient for number of rooms is nearly twice as large in the polluted stream equation as in the clean stream equation. Likewise, the negative impact of age of the house when more than twenty-five years old is significantly greater in polluted areas. This finding takes on greater practical importance when one realizes that 85% of the houses in the polluted stream sample and 60% in the clean stream sample are over twenty-five years old.

[2] Preliminary analysis showed such interaction to be present. These interactions were tested and one, the interaction of water quality and percentage change in population, was selected to be included in the empirical model. That variable is entered in the paired sample approach in place of percentage change in population.

Table 2. Effect of Selected Variables on the Value of Residential Properties along Clean Streams and Polluted Streams

			Mean Values		Coefficient Values	
	Units	Expected Sign	Clean Streams	Polluted Streams	Clean Streams	Polluted Streams
pH	*pH* units	+	7.190	4.500	3.322***	.532
					(1.209)	(.457)
Flood Hazard	probability	−	.099	.035	−.283	−.892**
					(.195)	(.377)
Interaction of pH_D and change in population	%	+			.062***	.164***
					(.026)	(.057)
Lot size	acres	+	.940	.890	.345**	.306**
					(.137)	(.119)
Number of rooms	number	+	8.800	9.260	.389**	.639***
					(.195)	(.135)
Potential employment	number of jobs	+	1040.000	1128.800	.292***	.148***
					(.049)	(.045)
Per pupil expenditure	$	+	1022.500	995.050	.868	2.076**
					(.565)	(.896)
Age of house (10–24)	0,1	−	0.200	0.110	−.126	−.415
					(.207)	(.284)
Age of house (25–49)	0,1	−	0.200	0.300	−.216	−.804***
					(.211)	(.272)
Age of house (50 and over)	0,1	+ or −	0.400	0.550	−.394*	−1.208***
					(.208)	(.270)
Income (>$10,000 = 1)	0,1	+	0.500	0.630	.195***	.168***
					(.075)	(.077)
Constant					−6.567	−7.872
$\bar{R}^2$					.74	.65
N					93	119

Note: Standard errors in parentheses. Asterisks denote significance: *** for above 1%; ** for between 1% and 5%; * for between 5% and 10%.

Conclusions

The results of various forms of estimating the model show that water quality significantly affects the value of adjacent residential properties. This is true when either an index of measured water quality characteristics is used or the owners' perceptions of water quality are used. The separate analysis of clean streams and polluted streams revealed that variation in pH has a large and significant effect on property values adjacent to clean streams but no effect on property values adjacent to polluted streams. One explanation of this finding is that increases in pH within the normal range (6.5–8.5) has increased value to property owners because it permits additional recreational activities, such as trout fishing. Increases in pH below the normal range (i.e., 3.7–5.5 in this study), however, permit no additional recreational activities and therefore, have no value.

Other variables found to be statistically significant as determinants of residential property value include the age of the house, lot size, number of rooms, potential employment, income, percentage change in population, per pupil expenditure on schools, and flood hazard.

Of equal importance with the finding of the relationship between stream acidity and property values is the demonstration that analysis of real estate markets can measure at least some of the value of environmental quality. This success can be attributed to two features of this study. First, the study examined a type of environmental quality that has noticeable effect on the buyers of the type of real estate studied. The relationship between water quality and rural nonfarm residences may be much clearer than some other environmental quality-property value relationships. Second, this study used primary data on individual properties and property owners to estimate directly the effect of all variables theoretically linked to property values. This contrasts sharply with some of the previous studies which employed proxy variables and applied them to aggregate units of property, such as a census tract. Direct estimation using the actual units of decision avoids losing the environmental effect through poor specification and certainly makes interpretation of the results more straightforward.

[*Received June 1978; revision accepted November 1978.*]

References

Al-Ani, K. S. "The Relationship of Water Quality to Residential Property Values." Ph.D. thesis, Pennsylvania State University, 1977.

Bator, F. M. "The Anatomy of Market Failure." *Quart. J. Econ.* 72(1958):351–79.

Klein, L. R. *An Introduction to Econometrics*. Englewood Cliffs, N.J.: Prentice-Hall, 1962.

Mishan, E. J. "The Postwar Literature on Externalities: An Interpretive Essay." *J. Econ. Lit.* 9(1971):1–28.

Nagadevara, V. S., E. O. Heady, and K. J. Nicol. *Implications of Application of Soil Conservancy and Environmental Regulations in Iowa within a National Framework*. CARD Rep. 57, Iowa State University, 1975.

National Academy of Science, Committee on Water Quality Criteria, Environmental Studies Board. *Water Quality Criteria*, Washington D.C., 1972.

Pennsylvania Department of Environmental Resources. *Pennsylvania Water Quality Network, Sampling Station Descriptions*. Pub. No. 33, 1975.

Pound, C. E., R. W. Crites, and D. A. Griffes. *Costs of Wastewater Treatment by Land Application*. Environmental Protection Agency. EPA-430/9-75-003, 1975.

Rosen, S. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *J. Polit. Econ.* 82(1974):34–55.

Samuelson, P. A. "The Pure Theory of Public Expenditures." *Rev. Econ. and Statist.* 36(1954):387–89.

Turvey, R. "Divergencies between Social Cost and Private Cost." *Econometrica* 30(1963):309–13.

U.S. Department of Commerce. *Survey of Current Business*, vol. 56, nos. 1 and 12, 1976.

Van Note, R. H., P. V. Hebert, and R. M. Patel. *A Guide to the Selection of Cost Effective Wastewater Treatment Systems*. Environmental Protection Agency, EPA-430/9-75-002, Washington, D.C., 1975.

Young, C. E. *The Cost of Land Application of Wastewater: A Simulation Analysis*. USDA ERS Tech. Bull. No. 1555, 1976.

Procedures in Estimating Benefits of Water Quality Change

Nicolaas W. Bouwes, Sr. and Robert Schneider

Wisconsin water resource managers have determined that the water quality in Pike Lake is deteriorating rapidly. The source of this problem resides with the fact that storm sewers empty directly into the lake, delivering large nutrient loads. The impending decline can be prevented by the construction of a storm sewer diversion project. This undertaking can be accomplished for a fixed cost of \$175,000—operation and maintenance costs are considered negligible. The question being asked by the resource manager is whether the benefits to be derived from preserving the present high level of water quality will justify the project cost.

Although the foregoing is hypothetical, the problem is typical of those confronting today's decision makers. What insight can economics bring to bear on issues such as these? The purpose of this paper is to address such an issue by presenting a method for estimating, *ex ante*, the benefits of water quality change by (*a*) presenting the theoretical basis for the empirical analysis, (*b*) establishing the relationship between an objective measurement of water quality utilized by water resource experts and the subjective ratings of lake users, (*c*) presenting a model including recreators' ratings of water quality, and (*d*) synthesizing these components by advancing a method which is applied to the possible decision-making situation described above.

The Theoretical Model

Consistent with the notation used by Mäler, an individual's utility is represented as a function of consumption activities, C, and environmental services, Y:

$$(1) \qquad U = U(C,Y).$$

By assuming weak complementarity, i.e., those situations where the consumption of a private good is a necessary prerequisite of the enjoyment of a given environmental quality, it is possible to derive the benefits (costs) of a quality change in a public good from information on the demand for the private good. Embodied in this notion of weak complementarity is the assumption that there are no option values, or that if the demand for some private good is zero, then so is the marginal willingness to pay for some environmental quality. An example is the case of water-related recreation, the use of which is influenced by the level of water quality. Those who do not use the lake are then assumed to be indifferent to water quality changes.

It can now be shown that this condition will allow estimation of the demand price for the environmental service, e.g., recreation visits (V). When the quality of water is WQ_O, the income-compensated demand curve for recreation visits is D_0 as in figure 1. At the price P_O, the consumer demands V_O trips and has consumer surplus ABC. If the quality of water improves to WQ_1 it is assumed to increase the marginal utility per trip, thus shifting the demand to D_1. The new consumer surplus is the triangle DEC.[1] The question to be answered is how much is the consumer willing to pay for this change?

Calculation of the benefits associated with a change in water quality as represented by willingness to pay can proceed in three steps. (*a*) A change in price from P_0 to P_1: given the demand curve D_0, the individual must be compensated by the corresponding consumer surplus ABC so as not to be made worse off by the price change. (*b*) A change in WQ: given the assumption of weak complementarity, the consumer's utility is unaffected and thus there is no need for compensation. (*c*) A change in price back to P_O: the consumer is willing to pay the new consumer surplus as represented by the area DEC. The net result is the difference between the consumer surplus before and after the water quality change. In other words, the consumer would be willing to pay $BADE$ for a change in water quality. The first step in making such a determination is the estimation of the demand curve for recreation, as measured by trips (V), including a shift variable which is a function of water quality.

Nicolaas W. Bouwes, Sr., is an agricultural economist with the Natural Resources Economics Division, ESCS, U.S. Department of Agriculture, and an assistant professor of agricultural economics at the University of Wisconsin. Robert R. Schneider is an assistant professor of economics at Williams College.

The authors wish to thank Thomas Crocker, Richard Dunford, Russell Gum, William Martin, Louise Love, Daniel Bromley, and referees from this *Journal* for helpful comments on drafts of this paper. Any errors are the responsibility of the authors.

[1] Although the assumptions required to use consumer surplus often appear restrictive, Willig has demonstrated that this need not necessarily be the case. He states that in those instances where the consumer's income elasticity is in the range of ± 1.0, and "if the surplus area under the demand curve between the old and new prices is 5 percent of income (or less), then the compensating variation is within 2 percent of the measured consumer's surplus" (p. 590). Both of these conditions are realistic for the case at hand.

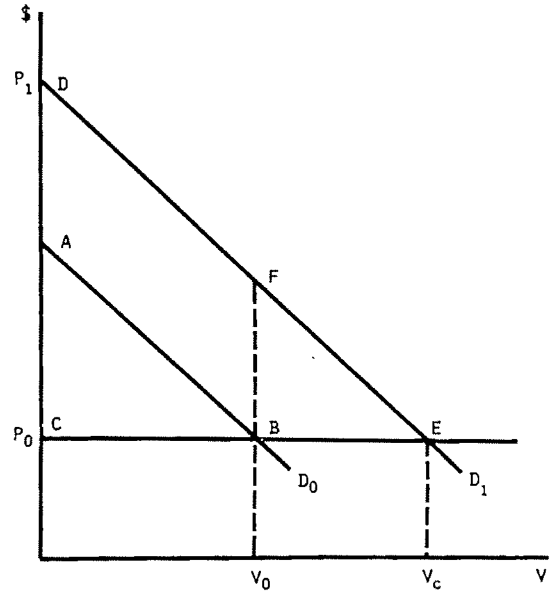


Figure 1. Benefits under complementarity conditions

Hotelling pioneered the travel-cost method for evaluating a recreational resource, and further refinements were provided by Trice and Wood, and Clawson. This approach is well documented, so no elaboration is required. The willingness-to-pay technique, a conceptually similar method credited to Davis, directly estimates consumer surplus through an interview procedure. Both of these methods have been applied to evaluating the total recreational resource, but not in assessing the value of a resource attribute such as water quality.

Some of the previous efforts to estimate the effect of a change in water quality on value of recreation resources have concentrated on the estimation of those benefits that would be attributable to the change in one or more of the physical parameters that contribute to the quality of water, e.g., recreation benefits increase as the dissolved oxygen concentration level rises (Kneese and Bower, Davis). Stevens hypothesized that the quality of the recreation experience (fishing) is a function of angling success per unit of effort, which reflects water quality. Reiling, Gibbs, and Stoevener employed use-intensity factors for swimming, fishing, and water skiing as a proxy for water quality. In the latter case, the indices were subjective estimates, by Forest Service and Environmental Protection Agency employees, of the amount the lakes were used for various activities. The major shortcoming in these research efforts is that the techniques do not contain a systematic relationship between the subjective index used as a proxy for water quality and physically measurable water quality parameters. Perhaps more important, these indices do not reflect recreators' perceptions of water quality.

Objective and Subjective Water Quality Relationship

Ultimately, the existence or nonexistence of benefits emanating from a water quality change are determined by whether an improvement is perceived by the affected water user. Thus, to estimate adequately the benefits associated with water quality changes, it is necessary to predict how lake users perceive water quality. However, water resource experts do not deal with the subjective form of rating as would the typical recreator, but in more objective, measurable terms such as turbidity, dissolved oxygen, and BOD in parts per million, etc. It is therefore necessary to determine if there exists a relationship between the more objective water quality measurements as utilized by the scientists and the subjective rating of water quality as perceived by the lake users.

To ascertain the existence of the relationship, it was necessary to seek out a water quality index that would be readily amenable to testing. The choice was Uttormark's Lake Condition Index (LCI) which was recently developed to classify all Wisconsin lakes larger than 100 acres, providing a system to facilitate resource decision making. One of the main considerations in developing the LCI was to produce an inexpensive lake classification system. Thus, the existing availability of data greatly influenced the choice of parameters used to classify lakes. The lake water quality parameters used to evaluate the lakes are dissolved oxygen in the hypolimnion, secchi disk transparency, fish winterkill, and the extent of macrophyte or algae growths. Penalty points are assigned to these parameters, depending upon the degree to which they exhibit undesirable symptoms of water quality, and then added to produce the relevant LCI. The possible range is zero to twenty-three points, with these amounts representing the finest and poorest levels of water quality, respectively. The resulting classification system was tested by comparisons with other more data intensive studies, the relative ranking of lakes to that of area resource managers, and consistency in ranking when lake information generated from other studies was used with the LCI method—in each instance the LCI compared favorably. For purposes of this study, the LCI bears three advantages over other indices: (*a*) it provides a simple scaler for lake classification, much like what could be expected of the average lake user; (*b*) it has been used to rate all Wisconsin lakes in excess of 100 acres; and (*c*) it is relatively simple.

Data used to test the relationship between subjective and objective water quality rating were obtained by on-site interviews at eight southeastern Wisconsin lakes. In addition to the standard cost, time, and demographic questions, respondents were asked perceptual questions regarding water quality of that particular survey lake. Specifically, recreators were asked to rate the lake water quality on a zero to twenty-three scale, such as that employed by the LCI. The effectiveness of the LCI in

predicting the public's perception of water quality was tested by regressing the average rating ($\bar{R}$) of all recreators for each lake on the corresponding LCI for that lake. The results of this analysis were encouraging, yielding the working equation

$$\ln \bar{R} = 1.948 + \underset{(3.37)}{.0364}\ \text{LCI}, \tag{2}$$

where the values in parentheses are computed t-values, the sample size was 7 and the R^2 .694. Equation (2) will be utilized within the resource evaluation model below to predict the changes in recreators' perceptions of water quality.

The Statistical Model

The general form of the model used to estimate water quality benefits is of the Clawson-Hotelling genre:

$$V_{ij} = \alpha + \sum_{k=1}^{n} \beta_{ik} X_{ijk} + e_{ij}, \tag{3}$$

where V_{ij} is the number of visits by decision-making unit i to lake j, X_{ijk} is the value for the independent variable k for the decision-making unit i at lake j, and e_{ij} is the error term. The primary objective is to produce a statistical demand curve with reliable estimates of the structural parameters—particularly those of the cost variable from which the resource value is derived, and that of the water quality variable which is used to determine the economic significance of a water quality change.

The final estimated demand curve for visits from the regression analysis is

$$\begin{aligned} V_O = 43.22 &- \underset{(.950)}{.317}\, C + \underset{(2.10)}{.008}\, C^2 \\ &- \underset{(2.93)}{5.264}\, \ln \bar{R} - \underset{(3.63)}{.162}\, T \\ &+ \underset{(2.81)}{.0003}\, T^2 - \underset{(2.35)}{.321}\, I, \end{aligned} \tag{4}$$

where V_O is number of visits for the year, C is total variable cost per trip, $\bar{R}$ is recreator's rating of water quality, T is round-trip time and I is recreator's annual income. For this regression, the sample size was 195 and the R^2 .203. The low t-value on cost may reflect the possibility that time is perhaps a more binding constraint than costs when considering relatively short day trips. The income coefficient carries a negative sign and may suggest that recreators tend to substitute other activities for day trips as income increases. The rating variable proved to be consistent in this and other model specifications, demonstrating a level of significance of approximately 1% or better.

It was realized that other site amenities might contribute to users' perceived ratings; thus, the survey lakes were chosen so that they were as similar as possible except for water quality. That is, the lakes were of similar size, ranging between 400 and 600 acres; location choice was made so that physiographic characteristics would be comparable; and lake sites possessed many of the same amenities deemed desirable by lake day-users, such as lifeguards, boat launching facilities, and beaches.

The data used to estimate the above demand curve are in the form of individual observations rather than the commonly employed zone averages. The justification for this approach lies in the fact that without the inclusion of time in the estimated demand equation, the cost coefficient generally will have too great a magnitude and, hence, an under-evaluation of the resource value. However, when zone averages are employed, there exists a high degree of multicollinearity between cost and time; thus, time has been excluded in most evaluation procedures. Estimation procedures based on individual or group observations avoid this problem. However, the resulting R^2 is reduced considerably, even though the t-values on the estimated parameters will be high. For purposes of resource evaluation, concern is more with the level of significance of the individual variable than with the magnitude of the coefficient of determination (Brown and Nawas, p. 249; Gum and Martin, p. 560). In this study it is the cost variable that is used in evaluating the resource and the shifter variable, rating, that is of interest.

Economic Benefits under Current and Alternative Water Quality Conditions

To estimate the resource value under current water quality conditions, a two-step evaluation process, as used by Gum and Martin, was employed. This approach requires applying a derived statistical demand curve to each individual observation, using the recreator's observed cost and visit data to reflect behavior at zero additional site cost. This is then used to estimate an aggregated demand curve for the total recreation experience from which the resource value is estimated.

For example, by introducing a change in costs term, c, into equation (4) the estimate of visits becomes:

$$\begin{aligned} V_c = 43.22 &- .317\,(C + c) + .008\,(C + c)^2 \\ &- 5.264 \ln R - .162\, T + .0003\, T^2 - .321\, I. \end{aligned} \tag{5}$$

By subtracting equation (5) from equation (4), the individual decision-making unit's demand curve can now be represented by equation (6),

$$V_c = V_O - .317\, c + .016\, Cc + .008\, c^2. \tag{6}$$

The evaluation of the resource is accomplished by using equation (6) to estimate an aggregated demand curve. This is done by applying it to the cost and visitation data of each of the representative decision-making units. Costs (c) are increased until the number of trips equals zero or starts to increase.

As it is illogical for the number of trips to increase as costs increase, thus, trips are set equal to zero in the latter instance (Gum and Martin). This result is then expanded by the representation rate of that observation. The representation rate or weighting factor is determined by the response rate: the total number of recreators divided by the product of the average number of trips and party size of the sample and the number of observations in the sample. These expanded individual demand curves then are summed horizontally to construct the aggregate demand curve from which the resource value is estimated, e.g., the area under this curve reflects the consumer surplus associated with the resource.[2]

To estimate the annual benefits associated with a change in water quality, i.e., *BADE* in figure 1, it is necessary to determine how a change in water quality will modify recreator's behavior. The change in water quality is reflected in the model so that the initial number of trips is more or less than under previous water quality conditions, i.e., $V^*_0 \gtrless V_0$, where the difference is 5.264 ($\Delta ln\ \bar{R}$) having been estimated by equation (2). Substituting V^*_0 for V_0 in equation (6) gives the desired result.

The resulting change in resource value under various levels of water quality can be determined by calculating the difference between the initial resource value and that occurring after the water quality change.

A Water Resource Management Scenario: The Problem and Solution

To perform an *ex ante* analysis of the hypothetical problem we presented our resource manager above it is necessary to (*a*) establish the resource value with current water quality conditions; (*b*) determine the impact on users' perceptions of the potential decline in water quality; and (*c*) estimate the decline in resource value that would be avoided by the project.

To demonstrate the effects on resource evaluation of a change in water quality, it is necessary to determine the number of recreators that utilize the resource with current water quality conditions. The number of individual recreators to visit Pike Lake for the year prior to the survey, 1975, was 168,629. This will be assumed to be an approximation of the number for the current year. This count is considered accurate, as access to the lake is limited to supervised entrances where head counts are taken. It is determined from the survey data that the average number of trips per party during the previous season was 13.9 trips and average party size was 6.15 persons, yielding 1,972 different parties, or approximately 27,400 total group visits at the lake over the course of the year.

With this information and the pertinent individual group information required by equation (6), it is possible to estimate the resource value under current water quality conditions by employing the procedure described above. The results of the computations are presented in table 1, which reflects resource value as $429,038.

The next step in this method requires that we estimate how the expected change in water quality, i.e., ΔLCI = 7, will affect the recreator's perceived rating. This movement will be predicted by the use of equation (2). Repeating the resource evaluation procedure as before, but employing the modified form of (6), i.e., with V^*_0 substituted for V_0, it is possible to estimate what the potential loss in benefits would be with deteriorated water quality conditions. These results are also presented in table 1 and the resource value is now $390,074. Thus, the estimated annual benefits, i.e., area *BADE* in figure 1, would be $429,038 − $390,074, or $38,964. This amount, as in most of these recreational analyses, may represent somewhat of an overestimation as substitutes and alternative activities are not accounted for. One possible way to mitigate this would be to determine the lower limit of benefits, thereby constructing a range of possible benefits. Reconsider the case in figure 1, but rather than allowing the recreator to expand the number of trips taken to V_1 we restrain him to V_0, his original number of trips, and calculate the corresponding consumer surplus, *BADF*, thereby not concerning ourselves with substituting one activity with another. Now we have established the range between *BADE* and *BADF*. If the range is narrow, the substitution effect can be considered minor.

The present value of the benefit stream, assuming a modest twenty-year period and 10% discount

Table 1. Resource Value with Alternative Water Quality Conditions

	Present Conditions (LCI = 3)		Expected Conditions (LCI = 10)	
Added Cost per Trip ($)	Total Group Trips	Total Revenue ($)	Total Group Trips	Total Revenue ($)
0	26,996	0	24,383	0
3	25,632	76,896	23,195	69,584
6	24,577	147,461	22,282	133,692
9	23,820	214,379	21,617	194,553
12	21,521	258,247	19,535	234,420
15	21,264	318,957	19,305	289,582
18	13,966	251,392	13,111	236,002
21	0	0	0	0
Consumer Surplus Value		$429,038		$390,074

[2] It is necessary to assume here that the demand functions are aggregates of homogeneous groups of recreators, i.e., similar tastes and preferences, react the same to price changes, etc. (Mäler p. 184). This assumption is mitigated by the use of individual observations (Gum and Martin p. 564).

rate, is $331,740. Given the expected costs and benefits associated with this project, it would appear to be a wise decision for the water resource manager to recommend the project.

[*Received October 1977; revision accepted February 1979.*]

References

Brown, William G., and Farid Nawas. "Impact of Aggregation on the Estimation of Outdoor Recreation Demand Functions." *Amer. J. Agr. Econ.* 55(1973): 246–49.

Clawson, Marion. *Methods of Measuring the Demand for and Value of Outdoor Recreation*. Washington, D.C.: Resources for the Future. Reprint 10, Feb. 1959.

Davis, R. K. *The Recreation Value of Northern Maine Woods*. Ph.D. thesis, Harvard University, 1963.

Gum, Russell L., and William E. Martin. "Problems and Solutions in Estimating the Demand for and Value of Rural Outdoor Recreation." *Amer. J. Agr. Econ.* 57(1975):558–66.

Hotelling, Harold. "The Economics of Public Recreation." *The Prewitt Report*. Mimeographed. Washington, D.C., Dept. of the Interior, National Park Service, Land and Recreation Planning Division, 1947.

Kneese, A. V., and B. T. Bower. *Managing Water Quality*. Baltimore, Md.: Johns Hopkins University Press, 1968.

Mäler, Karl-Goran. *Environmental Economics*. Baltimore, Md.: Johns Hopkins University Press, 1974.

Reiling, S. D., K. C. Gibbs, and Herbert Stoevener. *Economic Benefits from an Improvement in Water Quality*. Socioeconomic Environmental Studies Series. Washington, D.C., U.S. Environmental Protection Agency, Jan. 1973.

Stevens, Joe B. "Recreational Benefits from Water Pollution Control." *Water Resour. Res.*, vol. 2, no. 2 (Second Quarter, 1966):167–82.

Trice, A. H., and S. E. Wood. "Measurement of Recreation Benefits." *Land Econ.* 34(1958):195–207.

Uttormark, Paul D., and J. Peter Wall. *Lake Classification—A Trophic Characterization of Wisconsin Lakes*. Corvallis, Ore.: U.S. Environmental Protection Agency, Environmental Research Laboratory, 1975.

Willig, Robert D. "Consumer Surplus Without Apology." *Amer. Econ. Rev.* 66(1976):589–97.

The Demand for Agricultural Research: A Colombian Illustration

Grant M. Scobie

The generation of new technology has come to be viewed as an economic activity to which scarce resources can be devoted, and for which measurable output can be defined (Schultz 1970). Society, either individually or collectively, makes conscious investment decisions to allocate resources to research activities with the expectation that the present value of some future income streams resulting from the technological advances will exceed the cost of their generation. This leads naturally to the concept of efficiency of resource use and the evaluation of whether the research expenditures constituted a socially profitable use of resources. Griliches, Peterson, Ayer and Schuh, and Duncan provide well-documented examples of the analysis of the returns to investment in agricultural research. Evenson (1975, 1976, 1977) recently has extended these studies to encompass the returns to the international diffusion of innovations.

In addition to the efficiency criterion, economists increasingly have focused attention on the distributional impact of technological change. Typically a comparative static Marshallian framework is used to estimate the gross social benefits accruing to producers and consumers (e.g., Akino and Hayami). This is accomplished by comparing the producer and consumer surplus with and without the technological change, which is captured by a displacement of the product supply curve. The procedures for measurement of the relevant areas, questioned by Scobie, have been clarified recently (Jarrett and Lindner, Lindner and Jarrett, Sarhangi et al.).

Other researchers have considered the impact of innovation on functional income shares (Ayer and Schuh, Wallace and Hoover). More recently, Scobie and Posada (1977, 1978) examined the impact of research-induced benefits and costs on the distribution of household income at the national level. The increased attention to distributional impacts reflects an important step in the development of a more complete analysis of technological change, one in which the economic and political forces leading to the generation of new technology are themselves related to and explained by matters of efficiency and equity. In short, a conceptual framework is sought in which technological change becomes a truly "endogenous" element.

Hayami and Ruttan have offered relative factor prices as an engine governing the force and direction of technological change, and Ruttan (1973, p. 46) extends the "induced innovation perspective to include the process of institutional innovation" (see also Ruttan 1978). The demand for publicly financed research is explained by Guttman in terms of political interest groups, i.e., the beneficiaries of the research. De Janvry (1977) has developed an explicit model of generation of new technology in which he identifies the determinants of the supply of and demand for technological change, again sharpening the focus on the sociopolitical interdependencies. While being a relatively complete statement of the dialectical process which generates technological and institutional change, enormous empirical challenges remain. De Janvry's attempt to construct a social payoff matrix for Chile or the work of Evenson (1977) in constructing measures of research output serve to caution the ambitious. However, economists must venture beyond the mechanical calculation of internal rates of return to historical research programs and continue to enrich their models with social and political dimensions.

This paper examines the process of technological change in the Colombian rice sector. An attempt is made to articulate some of the political and economic forces that governed the demand for new technology and which influenced (and were influenced by) the distribution of costs and benefits. The Colombian experience is instructive, as it permits an analysis of an apparent paradox: namely, the simultaneous investment in research and discrimination against the agricultural sector.

Background

Since 1957, an extensive and successful program of rice research has been conducted in Colombia. The high-yielding varieties bred and adapted for irrigated culture were instrumental in the fivefold rise in output between 1957 and 1974. The real domestic price of rice fell as a consequence, and consumers

---

Grant M. Scobie is an assistant professor in the Department of Economics and Business, North Carolina State University.

Paper No. 5909 of the Journal series of the North Carolina Agricultural Research Service, Raleigh.

The support and interest of John L. Nickel, Director-General of CIAT, and Peter R. Jennings of the Rockefeller Foundation are gratefully acknowledged. Improvements on earlier drafts followed from the insightful comments of G. Edward Schuh, T. W. Schultz, Paul R. Johnson, Alberto Valdés, Per Pinstrup-Andersen, and Reed Hertford. The responsibility for residual scientific solecisms must abide with the author.

(rather than producers) were the principal beneficiaries of the research. The rise in output was sufficiently marked that the investment in the research generated an internal rate of return probably exceeding 80% (Scobie and Posada 1978).

The demand for research (and implicitly technological change) was expressed by three groups, each of which contributed to the funding of the research. Specifically, these "demanders" were (*a*) producers of rice (who paid a research levy on each unit of production, (*b*) consumers (whose tax revenues were channeled through the national fisc to the research program), and (*c*) international donors (initially the Rockefeller Foundation and, later, indirect support of the Centro Internacional de Agricultura Tropical). To explain the existence and the relative magnitudes of the contributions by these groups of demanders of technological change is the purpose of the next section.

The Demand for Research and Technological Change

A basic premise is that the distributional outcome of the new rice technology followed as a result of economic policies adopted at the national level, not directly related to the rice sector. Specifically, Colombia's industrial protection policy, through the use of tariffs against imported manufactured goods, has a three-pronged bias against the agricultural sector, including, of course, the rice production sector. In the first place, the price of manufactured inputs used by agriculture are raised. Second, returns to investment in manufacturing are augmented by the tariff barriers, encouraging more domestic resources to flow into the industrial sector. Availability of resources to agriculture is thereby reduced or, alternatively, their prices inflated, making the generally unprotected agricultural sector less competitive. Finally, and most important in the present context, the price of foreign exchange could be maintained artificially low (Scobie and Johnson), making the export of products less attractive. This bias against the agricultural sector has been documented widely (Schuh 1968, and Valdés). Little, Scitovsky, and Scott note (pp. 177–78), "Protection of manufacturing produces a bias against agriculture, in that it reduces resources available for agricultural investment, as well as reducing the incentive to produce and sell, especially as far as exports are concerned. . . . Our view is that the bias has been excessive; that in several of the countries the effect on agricultural production has been damaging, and that agricultural exports earn less than they should have done in most countries."

The Colombian case conforms to this general pattern. Certainly, almost no rice was exported during the period of rapid output growth (1968–74) that accompanied the introduction of modern varieties. This lack of exports was due, at least in part, to the relatively unattractive exchange rates facing potential rice exporters as a result of the industrial protection policy and the concomitant overvaluation of the peso. Nelson, Schultz, and Slighton review the political determinants of Colombian overvaluation.

The set of general economic policies, including tariff protection and the related price of foreign exchange, together with the particular mix of commodity policies which prevail at any point in time, are a product of continually evolving economic and political forces. These forces often are opposed, reflecting the interests of different groups. Producer organizations typically are concerned with presenting cases for remunerative farm prices and promoting exports. On the other hand, manufacturing groups press for tariff protection and overvalued exchange rates. Interestingly, such policies additionally have fostered cheap domestic food supplies in the presence of rapid agricultural innovation, thereby lowering the price of wage goods and indirectly subsidizing the price of labor to the manufacturing sector. As Barraclough notes, rapid urbanization, together with growth in the industrial, banking, and financial sectors, generally has increased the political weight of manufacturing relative to agricultural interests; Torres provides some specific estimates for Colombia. While the rice growers' organization (FEDEARROZ) has vigorously represented the interests of rice growers since its inception (Leurquin, pp. 241–44) and frequently won concessions favoring rice producers (e.g., a token export subsidy introduced in 1976), its influence has tended to be supplanted by national economic strategies promoted by an increasingly powerful entrepreneurial class whose political power base lies less and less with agricultural interests (Dix). The net result of these forces has been that the benefits of the new rice varieties were captured by consumers as a result of the cheap food policies which are consistent with and complementary to protection of the industrial sector.

As a result of the unfavorable price of foreign exchange, the expanded production was sold almost exclusively on the domestic market. As Harberger (1970, pp. 107–08) notes, "the basic principle here, of course, is that each new restriction on imports lowers the equilibrium exchange rate relative to the internal price level, thus reducing the market incentives facing the export trades." With a moderately inelastic domestic demand curve, internal prices fell, resulting in the capture of the net benefits by rice consumers. In discussing the overvaluation of the U.S. dollar, Schuh (1976, p. 8) argues that one consequence is a failure "to capitalize on its technical progress as a source of exchange earnings and instead would channel the benefits of technical change to the domestic consumer in the form of lower agricultural prices."

On the basis of the foregoing argument, one would expect that Colombian rice exports would have been much greater had a different exchange rate policy been pursued. However, to quantify the impact on exports, some estimate is needed of the

"true" value of foreign exchange. The social opportunity cost of foreign exchange (Harberger 1972, p. 125) was chosen as such a measure. It is given by $E_s = [\epsilon E - \eta\ (M/X)\ E(1 + t)]/[\epsilon - \eta\ (M/X)]$, where E is the nominal price of foreign exchange facing potential exporters, t the uniform ad valorem duty on imports, (M/X) the ratio of imports to exports, and ϵ and η are the elasticities of the private sectors' supply of exports and demand for imports. The values of ϵ and η were taken as 2.5 and −2.3, respectively (Johnson, p. 169). The "average" tariff level for 1975 was reported as 31% (Departmento Nacional de Planeación), but is generally believed to have been reduced substantially since 1970. The dynamics of this change lie beyond the present inquiry; only the existence of an import tariff is germane.

Using the estimates of E_s and the average FOB price received by six Latin America rice exporters, an implied domestic peso price was calculated. This price (adjusted for milling and transport) was used to estimate domestic supply and demand, the difference being the exports that would have prevailed at the more favorable exchange rate, assuming that Colombian exports would not depress external prices. The results are summarized in table 1.

The important conclusion is that at a more attractive exchange rate, Colombia would have been able to compete favorably in external markets, and exports would have been much greater than those actually recorded. In fact, by 1975 the domestic price of rice had fallen to a level which made exporting attractive (even at the nominal price of the peso), and Colombia will now possibly become a more consistent rice exporter. This will mean, however, that future direct benefits of new rice technology will be captured by producers and foreign consumers, rather than by Colombian consumers as has been the case.

If the demand for agricultural research by different groups is related to the expected benefits they receive, then the anticipation of an export trade should be reflected in an increasing share of the research costs being borne by the producers. The Colombian research program was undertaken specifically to lower domestic rice prices. Consistent with the potential payoffs, the research was wholly financed by consumers through the tax-supported national rice research program. Improved technical efficiency of rice production resulted, and producers began to visualize the prospects of an export trade. Through FEDEARROZ they proposed the research levy and became responsible for its administration. By 1975, when significant quantities were exported, rice producers were contributing almost twice as much as consumers to the funding of rice research. Consumer contributions had fallen absolutely and comprised only about 20% of the research funding. From 1957 to 1964, annual consumer contributions averaged 78% of the national funding for rice research; from 1965 to 1974, the shares of consumers and growers were 40% and 60%, respectively. The changing importance of producer and consumer financing of rice research is seen as being consistent with the potential distribution of benefits of technological change.

This conclusion in no way precludes the possibility that producers might be motivated to invest in research even in the absence of export trade. The U.S. experience suggests that producer-supported research is not inconsistent with an inelastic final demand. Given the atomistic and hetereogenic nature of agriculture, astute profit-seeking producers can capture rents to early innovation. "Prices drop, . . . this eliminates the quasi-rents of the early adopters, and they must again look for new technological opportunities. They do this by pressing the agribusiness firms and agricultural experiment stations to innovate further" (de Janvry 1978, p. 313). Producer contributions to rice research motivated by the quest for innovator rents may well explain the initial funding and conceivably even account for the increasing relative importance of producer contributions. However, that increase is also consistent with the expectation that Colombia would be an exporter.

Throughout the period since 1957, international donors have contributed to the funding. In the

Table 1. Simulated Exports of Colombian Rice Given an Estimate of the Social Opportunity Cost of Foreign Exchange: 1972–74

Year	Average Tariff Level (t)	Nominal Exchange Rate (E)	Social Opportunity Cost of Foreign Exchange[a] (E_s)	Latin American Export Price (FOB)	Implied Price in Colombia (FOB)	Simulated Exports of Milled Rice[b]	Actual Exports
	(%)	---- peso/$US	----	$(US)/ton	pesos/ton	---- (thou. tons)	----
1972	45	22.80	28.13	164	4,613	203	3
1973	40	24.89	29.87	212	6,332	198	20
1974	35	28.69	34.22	333	11,395	456	1

[a]For formula, see text.
[b]Calculated as difference between domestic supply and demand (Scobie and Posada 1978, pp. 91–92).

main, these funds come from developed countries, which tend to be temperate zone importers of tropical products (the United States, in the case of rice, being an exception). The potential benefits to their consumers through cheaper imports of tropical products may not be an irrelevant consideration in voting public funds for agricultural research in the tropics. As Josling (p. 169) notes, "crops such as cassava (whose research is heavily supported by Canada) are finding outlets as animal feed in the developed country markets." In addition, investment in enhanced agricultural productivity broadens the market for the developed world's manufactured exports and helps create a more favorable economic and political environment for the operation of its multinational enterprises.

Viewed in this light, the Consultative Group on International Agricultural Research (CGIAR), which channels funds to the network of tropical research centers, represents an institutional mechanism of the developed countries for investing in tropical research. The returns to that investment come, in part, from cheaper imports, increased export demand, and an enhanced environment for multinational business. One should not infer that humanitarian motives are irrelevant: merely that the developed nations' investment in less-developed countries' (LDC) agricultures does have an economic rationale. Crawford (p. 281), commenting on the formation of the CGIAR, notes that "impetus for this action was the desire to encourage a greater research effort aimed at assisting developing nations to increase the quantity and improve the quality of their agricultural output and thus to raise standards of living." However, he continues, "all parties realized that increased agricultural productivity was essential to economic and social development in the great majority of these countries."

This mechanism for international investment in tropical research is becoming increasingly important relative both to the private- (e.g., United Fruit Co.) and public- (e.g., the U.K. Tropical Products Institute) sponsored research, which characterized the colonial and interwar periods, and to the bilateral aid programs of the fifties and sixties. The evolving institutional mechanisms for investment in developing agricultures can be viewed, at least in part, as serving the same ends as these precursors while presumably being more internationally palatable.

Concluding Remarks

A mixture of public, private, and foreign funds were combined to support a varietal research program for the Colombian rice industry. The net benefits of the ensuing technological change appear to have been captured disproportionately by low income consuming households (Scobie and Posada 1978, table 4). In the presence of a protective tariff structure, an industrially dominated body politic has the incentive to invest tax revenues in research, as additional output would lower the domestic price of a principal wage good. Rice is the major source of calories and the second most important source of protein in the Colombian diet, and between 1970 and 1974 its retail price fell by 46%, 65%, and 90% relative to beans, cassava, and potatoes.

Grower contributions to the research program have become relatively more important over time. As the new technology continued to lower domestic production costs, the possibility of exporting became a reality, and, in fact, exports rose to 175,000 tons in 1975. When facing a more elastic export demand curve, producers are likely to capture a greater share of the benefits of technological change.

In summary, the share of the costs of the research program borne by consumers and producers is consistent with the expected distribution of net benefits. Initially, the investment was met wholly by tax revenues. The explanation offered for this phenomenon is consistent with the cheap-food policies pursued by many developing countries. Discriminatory exchange rate policies and the accompanying stagnation of the agricultural sector generally constrain the demand for research (Schultz 1977). However, by investing in research and diffusion of output expanding technology, a dynamic agricultural sector can emerge even in the presence of an exchange rate distorted by a protectionist industrial policy. The increased production is diverted to the domestic market, lowering internal food prices. Use of tax revenues to finance agricultural research for basic food commodities is therefore seen as having a consistent economic rationale, even in the presence of a distorted exchange rate.

From the viewpoint of economic efficiency, one may want to dismantle the protective structure and operate in a "first-best" world. The present discussion takes the distortion as given and suggests that, on both efficiency and equity grounds, public investment in agricultural research may be justified. An alternative view is that the export sector justifies some compensation (which could be in the form of publicly subsidized research) for the tariffs awarded to the import-competing sector. Harris discusses this issue. This is quite apart from the argument that the product of agricultural research might be a collective good (Samuelson) that would be underproduced were its provision solely in the domain of private markets.

By considering some aspects of the political economy of investment in research, we resolve the apparent paradox of simultaneous discrimination against agriculture (through an overvalued exchange rate) and public funding of investment in research into basic food crops. Investment in the generation of new technology must continue to be an important strategy for enhancing agricultural output in the developing world. By viewing that investment in the context of competing economic

and, hence, political interests, richer insights are gained into the scope and limitations of publicly funded research as an instrument for enhancing economic growth.

[*Received December 1978; revision accepted February 1979.*]

References

Akino, M., and Y. Hayami. "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development." *Amer. J. Agr. Econ.* 57(1975):1–10.

Ayer, H. W., and G. E. Schuh. "Social Rates of Return and Other Aspects of Agricultural Research: The Case of Cotton in São Paulo, Brazil." *Amer. J. Agr. Econ.* 54(1972):557–69.

Barraclough, S. L. "Agricultural Policy and Land Reform." *J. Polit. Econ.* 78(1970):906–7.

Crawford, J. G. "Development of the International Agricultural Research System." *Resource Allocation and Productivity in National and International Agricultural Research,* eds. T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan. Minneapolis: University of Minnesota Press, 1977.

de Janvry, A. "Inducement of Technological and Institutional Innovations: An Interpretative Framework." *Resource Allocation and Productivity in National and International Agriculture Research,* eds. T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan. Minneapolis: University of Minnesota Press, 1977.

———. "Social Structure and Biased Technical Change in Argentina Agriculture." *Induced Innovation: Technology, Institutions and Development,* eds. H. P. Binswanger, V. W. Ruttan, et al. Baltimore, Md.: Johns Hopkins University Press, 1978.

Departmento Nacional de Planeación. *Analysis General de la Estructura Arancelarica Colombiana Vigente en Febrero, 1975.* Bogota: Unidad de Estudios Industriales, Documento DNP-UEI, 1975.

Dix, R. H. *Colombia: The Political Dimensions of Change.* New Haven, Conn.: Yale University Press, 1967.

Duncan, R. C. "Evaluating Returns to Research in Pasture Improvement." *Aust. J. Agr. Econ.* 16(1972): 153–68.

Evenson, R. E. "Agricultural Trade and Shifting Cooperative Advantage." *Trade, Agriculture and Development,* eds. G. S. Tolley and P. A. Zandrozny, Cambridge, Mass.: Ballinger Publishing Co., 1975.

———. "Comparative Evidence on Returns to Investment in National and International Research Institutions." *Resource Allocation and Productivity in National and International Agricultural Research,* eds. T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan. Minneapolis: University of Minnesota Press, 1977.

———. "International Transmission of Technology in the Production of Sugarcane." *J. Develop. Stud.* 12(1976):208–31.

Griliches, Zvi. "Research Costs and Social Returns: Hybrid Corn and Related Innovations." *J. Polit. Econ.* 66(1958):419–31.

Guttman, J. M. "Interest Groups and the Demand for Agricultural Research." *J. Polit. Econ.* 86(1978): 467–84.

Harberger, A. C. "Economic Policy Problems in Latin America: A Review." *J. Polit. Econ.* 78(1970): 1007–16.

———. *Project Evaluation.* London: Macmillan & Co., 1972.

Harris, S. F. "Tariff Compensation: Sufficient Justification for Assistance to Australian Agriculture?" *Aust. J. Agr. Econ.* 19(1975):131–53.

Hayami, Y., and V. W. Ruttan. *Agricultural Development: An International Perspective.* Baltimore, Md.: Johns Hopkins University Press, 1975.

Jarrett, F. G., and R. K. Lindner. "Research Benefits Revisited." *Rev. Mktg. and Agr. Econ.* 45(1977): 167–78.

Johnson, P. R. "Balance of Payments Pressure: The Colombian Case." *S. J. Econ.* 37(1972):163–73.

Josling, T. "Agricultural Trade: Implications for the Distribution of Grains from Technical Progress." *Trade Agriculture and Development,* eds. G. S. Tolley and P. A. Zadrozny. Cambridge, Mass.: Ballinger Publishing Co., 1975.

Leurquin, P. P. "Rice in Colombia: A Case Study in Agricultural Development." *Food Res. Inst. Stud.* vol. 7, 1967.

Lindner, R. K., and F. G. Jarrett. "Supply Shifts and the Size of Research Benefits." *Amer. J. Agr. Econ.* 60(1978):48–58.

Little, I., T. Scitovsky, and M. Scott. *Industry and Trade in Some Developing Countries: A Comparative Study.* London: Oxford University Press, 1970.

Nelson, R. R., T. W. Schultz, and R. L. Slighton. *Structural Change in a Developing Country: Colombia's Problems and Prospects.* Princeton, N.J.: Princeton University Press, 1971.

Peterson, W. L. "Returns to Poultry Research in the United States." *J. Farm Econ.* 49(1967):656–69.

Ruttan, V. W. "Induced International Change." *Induced Innovation: Technology, Institutions and Development,* eds. H. P. Binswanger and V. W. Ruttan, et al. Baltimore, Md.: Johns Hopkins University Press, 1978.

———. *Induced Technical and Institutional Change and the Future of Agriculture.* Proceedings of the 15th International Conference of Agricultural Economists, São Paulo, Brazil, 1973.

Samuelson, P. A. "The Pure Theory of Public Expenditure." *Rev. Econ. and Statist.* 36(1954):387–89.

Sarhangi, R. F., J. Logan, R. C. Duncan, and P. Hagan. "Who Benefits from Agricultural Research: Comment." *Rev. Mktg. and Agr. Econ.* 45 (1977):179–85.

Schuh, G. E. "Effects of Some General Economic Development Policies on Agricultural Development." *Amer. J. Agr. Econ.* 50(1968):1283–93.

———. "The Exchange Rate and U.S. Agriculture." *Amer. J. Agr. Econ.* 56(1976):1–13.

Schultz, T. W. *Investment in Human Capital: Role of*

Education and Research. New York: Free Press, 1970.

———. "Uneven Prospects for Gains from Agricultural Research Related to Economic Policy." *Resource Allocation and Productivity in National and International Agricultural Research*, eds., T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan. Minneapolis: University of Minnesota Press, 1977.

Scobie, G. M. "Who Benefits from Agricultural Research?" *Rev. Mktg. and Agr. Econ.* 44(1976):197–202.

Scobie, G. M., and P. R. Johnson. "Protection and the Exchange Rate: An Analysis of the New Zealand Foreign Exchange Market." *Econ. Record* 54(1974):534–54.

Scobie, G. M., and R. Posada T. *The Impact of High-Yielding Rice Varieties in Latin America with Special Emphasis on Colombia*. Centro de Documentación Economica para la Agricultura Latinoamericana (CEDEAL), Series JE-01, Centro Internacional de Agricultural Tropical (CIAT), Cali, Colombia, 1977.

———. "The Impact of Technical Change on Income Distribution: The Case of Rice in Colombia." *Amer. J. Agr. Econ.* 60(1978):85–92.

Torres, J. E. "Concentration of Political Power and Levels of Economic Development in Latin American Countries." *J. Develop. Areas* 7(1973):397–409.

Valdés E., A. "Trade Policy and Its Effect on the External Agricultural Trade of Chile: 1945–1965." *Amer. J. Agr. Econ.* 55(1973):154–64.

Wallace, T. D., and D. M. Hoover. "Income Effects of Innovation: The Case of Labor in Agriculture." *Amer. J. Agr. Econ.* 48(1966):325–36.

Kentucky's ANSER: The Agricultural Network Serving Extension and Research

David L. Debertin, Lynn W. Robbins, and Larry D. Jones

Kentucky's Agricultural Network Serving Extension and Research is a computerized information network that will deliver decision aids and can be used for data retrieval. Unlike some computer systems, ANSER is geared to serve the needs of many interests. The system is designed to meet the needs of a diversified clientele including farmers, county agents, rural development specialists, agribusinessmen, local political figures, and other decision makers. These clientele share a common need for up-to-date assistance in making knowledgeable decisions. The scope of ANSER is broad-based and comprehensive. By studying systems developed in other states, extensive planning by personnel in the college of agriculture has been done to ensure that the system has appeal to the diverse clientele of agricultural economics (Diesslin; Harsh; Kendrick, Thompson, Murray; Payne).

This paper (*a*) describes the design philosophy upon which the system's development was based, (*b*) outlines the software development effort, (*c*) describes the hardware selections, and (*d*) explains how clients will use the system.

Design Philosophy

Extension-oriented, computer-assisted, decision-making models have been developed following two distinct approaches. Advocates of the first approach argue that initial clientele acceptance will not occur unless programs are simple to use and require only a small amount of user-supplied data. Examples include many of the programs available on the CMN network (Chapman, Infanger, Robbins, Debertin), Telplan, and AGNET, such as those that calculate loan cost, break-even prices for livestock, and buy versus lease costs for farm machinery.

Advocates of the second approach argue that decision making is becoming increasingly complicated, and complicated decisions require assistance from complex, computerized decision models. For example, a computerized decision aid capable of modeling an individual farm in detail may require user input of 300–500 data items. This design may place substantially more demand on both the system's hardware and software components.

The Kentucky approach was to develop a system suited for both limited user data input systems and large-scale decision models. As a result ANSER will handle both interactive and batch processing on a decision maker-oriented rather than a researcher-oriented basis. This approach is necessary for, as Candler argues, extension software requirements are much more demanding than those of research. It is likely that such heavy requirements explain the slow adoption of computer-assisted decision making in extension.

Kentucky's ANSER network is designed to make full use of existing software that has been developed in other states as well as Kentucky. For example, many of the smaller scale programs on the CMN network will be adapted on ANSER. Programs would include calculating true interest rates, buying machinery versus lease, break-even prices, and investment capitalization programs such as calculating present value. Other large-scale programs are being adapted from Michigan, Ohio, Indiana, and South Carolina.

Work is taking place in Kentucky in designing input and output for existing research models to make them useful to extension clientele. The use of existing software in the ANSER Network has necessitated a choice of hardware that allows a high degree of flexibility. Four examples illustrate the integration of hardware choices and software development occurring at Kentucky.

Examples of Software Components: The Beef Simulator

The agricultural economics department, in conjunction with the departments of agricultural engineering, agronomy, and animal sciences have developed a large-scale simulation model of the beef-feed enterprises of a livestock farm in the Southeast (Smith et al.). The model simulates the growth of both plants and beef animals, energy requirements, cash flow, and net worth in a dynamic setting. Detailed descriptions of a farmer's land, labor, machinery, feed, money, resources, sources of credit, and other information are needed for model operation. Alternative management strategies for beef cattle production also are specified by the farmer. Output consists of forty pages of computer printout and

---

David L. Debertin is a professor, Lynn W. Robbins is an associate professor, and Larry D. Jones is extension professor of agricultural economics, University of Kentucky.

provides the farmer with detailed information with regard to the effects of alternative management strategies on the profitability of the beef enterprise.

KASH PROFITS

The KASH PROFITS program uses a linear programming model consisting of 116 rows and 185 columns (Debertin, Moore, Bradford, Jones; and Debertin, Moore, Jones). The output is designed to aid commercial corn-soybean farmers in planning crop patterns, making machinery acquisitions, and in the timing of planting and harvest operations. Farmer input is achieved by completion of an input form. Detailed information with regard to the availability of land, labor, and machinery, expected crop yields, and prices and other information is required.

The DISK System

The Development Information System for Kentucky (DISK) is a joint project sponsored by the department of agricultural economics and the department of rural sociology (Maurer and Pigg). The initial component of DISK is the development of a computerized retrieval system for socioeconomic data. Data for each Kentucky county on population, incomes, employment, and other social indicators are included in a format suitable for use by local decision makers.

While initial emphasis has been placed on building a data retrieval system, an analysis component also is being developed. Seven graduate students currently are working on research projects that will generate models eventually to become part of the analysis component. These models are designed to simulate and predict county level agricultural production commodity by commodity, taxation and revenue, employment, population, and transportation. Each is being designed for use in a problem-solving setting. Users will be public or private decision makers who have access to a computer terminal. Most will make use of data stored within the data retrieval component of DISK. Potential clients of the DISK system include county agents, public officials such as mayors and county judges, development administrators and planners, and other local citizens.

Buying (Selling) Beef for Home Freezers

A FORTRAN program is being developed which will assist consumers in deciding whether or not to buy bulk beef for home freezers. Input includes type of purchase, grade, yield grade, cost, and freezer space available. Output includes edible pounds of meat by cut, price per edible pound by retail cut, freezer space utilized, and freezer cost. One component of the model assists producers in evaluating how their asking price for a live animal translates into a price per edible pound of selected cuts of meat. This program is designed to run interactively on a computer terminal located at the local level.

Hardware Requirements

Each project places special requirements on the hardware configuration for ANSER. The beef simulation model uses a large amount of core, making access to a major CPU essential. The quality of input and output required by the model makes a conventional remote terminal impractical for user access. Because of the size of the output, high speed line printing is necessary.

The KASH PROFITS program also uses a substantial amount of core. In addition, access to a linear programming solver such as MPS 360 at the host computer is required. The KASH PROFITS program differs from the beef simulation model in that a smaller quantity of input is required. The output of the KASH PROFITS program consists of 654 lines. Hence, the KASH PROFITS program could be accessed at a remote terminal operating at 180 characters per second. However, if used in a workshop with forty to fifty participating farmers, a high speed line printer is required.

The information retrieval component of DISK is designed for access through a conventional remote terminal operating at low speeds (thirty characters per second). Most information retrievals result in tables consisting of 100 lines or less. A highly portable terminal is ideal for access to DISK. A portable terminal also makes easy access possible for the variety of potential clients of the DISK system.

The Beef Buying program for producers and consumers will run from a thirty characters per second terminal and requires hardware capable of handling interactive programs. The output will consist of less than 100 lines.

Systems Design

The selection of hardware components of ANSER is consistent with the requirements of software development efforts. The system consists of three major components: a host computer consisting of the current IBM 370-165 CPU at the University of Kentucky, minicomputers located at Lexington and at two regional centers, and remote terminals at county agents' offices. Associated with each minicomputer will be card-reading and line-printing capability at 600 lines per minute. Leased lines will connect the host IBM 370-165 with the minicomputers and the remote terminals. This gives the local county agent the full power of the IBM 370-165 twenty-four hours a day. Figure 1 illustrates the concept for the host computer located at Lexington, Kentucky, and one of the regional centers approximately 225 miles away from Lexington.

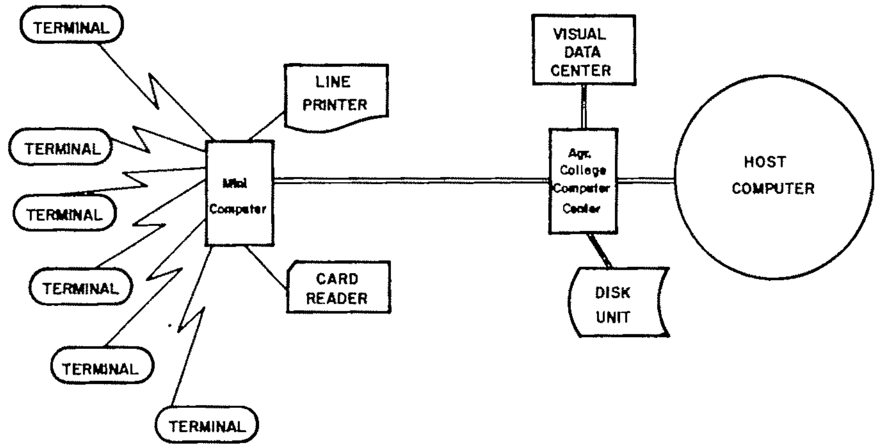


Figure 1. The host computer and the terminal system

The host computer will serve as the batch-processing unit for large models being used in the ANSER system. Linked to the host computer at Lexington will be a minicomputer in the agricultural college. This minicomputer will enable the host computer to be used interactively, and will preprocess input prior to processing by the host CPU, as well as do the complete processing of smaller programs. Card-reading and line-printing capabilities were selected to meet the needs of researchers in the agricultural college as well as extension personnel who wish to work with computerized decision models (such as KASH PROFITS or the beef cattle simulator) on campus. Sufficient disk storage space for the DISK project and other information systems that feature data retrieval will be located at Lexington and linked to the minicomputer.

Regional centers will be linked to the Lexington campus via a leased line. Minicomputers will serve as multiplexors so that multiple signals can simultaneously pass through the leased line. Card-reading and line-printing capabilities equal to those available on the Lexington campus will be available at each regional center. This will enable agricultural economists to hold workshops using batch-oriented, computerized, decision models with forty to fifty farmers in the western part of the state. Remote computer terminals to be located in county agents' offices will be wired into the minicomputer closest to their office.

County agents will be free to choose the type of computer terminal best suited to the software being accessed in the system. County agents located in the large, commercial, grain-producing areas probably will choose a nonportable terminal capable of printing 132 characters per line and operating at 180 characters per second. These are the requirements if KASH PROFITS software is to be accessed at the county agents' offices. Other counties may select a portable terminal capable of printing only 80 characters per line and operating at 30 characters per second. These parameters are compatible with the DISK software. Some counties may elect to purchase both a stationary and a portable terminal.

Computer programmers are employed for developing much of the input and output as seen by extension clientele. This work does not proceed without a complementary coordinated effort by state extension specialists within agricultural economics and other departments of the agricultural college. The state extension specialist will judge the suitability of a specific input and output design for his particular clientele. Moreover, the specialist who uses the software as part of an extension program bears responsibility for the accuracy of the software.

Table 1 provides an overview of the estimated costs of the completed computer network. Counties will each pay the one time cost of the computer terminal and be responsible for the cost of leased lines as well as maintenance. The college of agriculture will be responsible for the lease and maintenance of minicomputers and other equipment at the regional centers. The cost of computer time on the University of Kentucky computers will be shared by the county and the state.

Training of Clientele Groups

A major effort in the ANSER program is being devoted to the design of training facilities for county agents, community leaders, and other interested clientele groups. This effort has culminated in the building of the visual data center.

The visual data center is planned to serve three needs: (*a*) It will serve as a workshop center for efficient training of forty to fifty persons on the use of computer software available through ANSER. (*b*) It will be the center for working with farmers and others who are using models such as the beef cattle simulator and KASH PROFITS. And (*c*), it will serve as a place to bring clientele during the early testing of new software. A visual data center

Table 1. Estimated Hardware Costs for University of Kentucky ANSER Network

One Time Charges	Dollars per County	Total Dollars for 120 Counties, 3 Regional Centers
County computer[a] terminal-(cathode ray tube)	3,500	420,000
County printer (180) characters per second)[a]	3,000	360,000
total	6,500	780,000
Monthly Charges		
Leased lines for county terminals[a]	50/mo.	6,000/mo.
Maintenance of county terminals[a]	100/mo.	12,000/mo.
Lease of minicomputers,[b] line printers, and card readers at regional centers	1,700/mo.	5,100/mo.
Maintenance of regional center[b]	350/mo.	1,050/mo.
total	2,200/mo.	24,150/mo.

[a] To be paid by the County.
[b] To be paid by the University of Kentucky, College of Agriculture.

is currently being built at the agricultural college on the Lexington campus. Plans call for a visual data center to be located at the other regional centers.

Figure 2 illustrates the visual data center. The major equipment in the visual data center is a large screen television set suitable for viewing by forty to fifty persons. This television is wired to a computer terminal that outputs to a video signal. The terminal is linked to the minicomputer through to the host computer. Lines also connect portable terminals located on countertop space near each seat. The arrangement enables the instructor to display on the large screen television procedures to be used in accessing the computer. County agents, students, farmers, or others in the room will be able immediately to follow the same procedure using the terminal located directly in front of them. Incorrect responses by those in the room will become apparent immediately, because the output generated on the terminal can be compared easily with that on the large-screen television. This will provide for efficient instruction of large groups on proper terminal-operating procedures.

The room also is designed as an instructional area enabling the use of conventional video tape technology. Video tapes may include instructional aids designed to teach FORTRAN-programming fundamentals and keypunch operation, as well as video tapes in subject matter areas not directly related to computers.

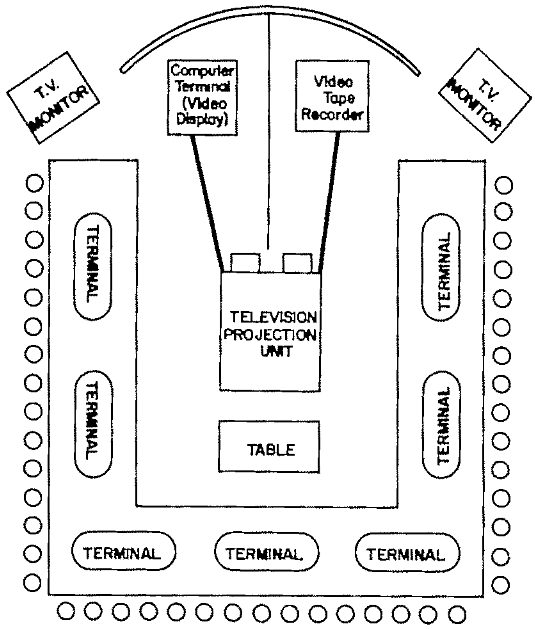


Figure 2. The visual data center

Implications

Does the ANSER system and the experience in designing it provide a basis for generalization? What design parameters, use intensions, projected utilization frequencies, manpower and resource requirements, and hardware costs are transferable? All would be transferable to a state that has the same environment that existed in Kentucky. While this is unlikely, the ANSER project has much to offer with respect to its design and utilization experiences.

That there is less to be gained in general from specific resource requirements and costs or costs estimated can be illustrated from what was planned initially with respect to the county delivery design. The original design consisted of nine minicomputers interfacing with the IBM 370. This was evaluated as the best method because of university policy with respect to centralized computing.

As the projected magnitude of computing grew, that policy was changed to allow the agricultural college to have its own computing capacity (still interfaced with the 370, however). This policy change allowed for a further cost saving. The new agriculture college computer allowed the network to be designed as explained. Three minicomputers were retained to allow concurrent usage by all of the Commonwealth's counties. This design also allowed the monthly leased line charge to be kept within reason.

The development of a computerized information network represents a multifaceted approach involving (*a*) identification of problems where computer-assisted decision aids would be useful, (*b*) design of

computer software useful in solving the problem as defined, and (*c*) the selection of hardware consistent with requirements imposed by the software. Recent advancements in computer technology are now making it possible to use with clientele extension software which a few years ago would be considered too complex or too costly. These advancements include: (*a*) the availability of terminal printers that operate at speeds much greater than thirty characters per second, making it possible to design interactive software for terminal use which generates much larger quantities of information for clientele than before; (*b*) the rapid decrease in the cost of on-line disk storage space, making possible the storage of large data banks with information available for instantaneous retrieval by clientele; and (*c*) cost reductions in processing capabilities—these cost reductions have made possible the decentralization of systems using minicomputers at remote locations with computers linked via leased telephone lines.

While progress has been made in the last decade, the development of comprehensive computer software for extension application continues to be a slow process. This process involves an integrated effort between both extension and research faculty. A computer network is not an end in itself but only a vehicle for the delivery of information to extension clientele. A well-designed computerized system will sell itself only if programs supply information of fundamental importance to clientele groups.

[Received August 1978; revision accepted February 1979.]

References

Candler, Wilfred, Michael Boehlje, and Robert Saatoff. "Computer Software for Farm Management Extension." *Amer. J. Agr. Econ.* 52 (1970):71–77.

Chapman, Carol A., Craig L. Infanger, Lynn W. Robbins and David L. Debertin. "Computers, Information and Community Development: A Review of State Extension Programs." *Taking Computers to the Community: Prospects and Perspectives.* Kentucky Coop. Extens. Serv., 1978.

Debertin, D. L., C. L. Moore, Sr., G. L. Bradford, and L. D. Jones. "Kash Profits—Kentucky's Advanced System Approach for Improving Corn and Soybean Profits With Computer Software." Kentucky Coop. Extens. Serv., 1977.

Debertin, D. L., C. L. Moore, Sr., and L. D. Jones. "Organizing, Conducting and Evaluating an Extension Workshop Using Computerized Decision Aids: The KASH PROFITS Experience." Kentucky Coop. Extens. Serv., May 1978.

Diesslin, H. G. "Fast Agricultural Communications Terminal System." Paper presented at the Annual Indiana Extension Conference, Purdue University, West Lafayette, Ind., 22 Oct. 1976.

Harsh, Stephen B. "A Progress Report on Telplan Activities." Agr. Econ. Staff Pap. 77–68, Michigan State University, Aug. 1977.

Kendrick, James, Thomas Thompson, and Pamela Murray. "AGNET: A Computer Network at Your Fingertips." *Farm, Ranch and Home Quart.*, Inst. of Agr. University of Nebraska, fall 1976.

Maurer, Richard C., and Kenneth Pigg. "Determining Local Development Information Desires and Needs in Kentucky: The DISK Project." *Taking Computers to the Community: Prospects and Perspectives.* Kentucky Coop. Extens. Serv., 1978.

Payne, M. A. "Computerized Management Network." *VPI CMN Office Users Guide.* Oct. 1975.

Smith, Edward M., Otto J. Loewer, Jr., et al. "Dynamic Simulation of Animal Growth and Reproduction." Paper 77-4511, Winter Meeting, American Society of Agr. Engineers. Chicago, Ill., 13–16 Dec. 1977.

Corn Acreage Response-Function Estimation with Pooled Time-Series and Cross-Sectional Data

James K. Whittaker and Robert L. Bancroft

A great deal of research has been done on the estimation of the parameters of acreage response models for various crops. Econometric acreage response studies have traditionally used more than twenty time-series observations to estimate the parameters of the model. A time period this long can include rapid advances in technology and changes in the acreage response coefficients.

The nature of technology makes it difficult to quantify. Crop technology is comprised of a large number of variables including advances in herbicides and pesticides, new types of machinery, improved varieties, and better farm management practices. Past acreage response studies have largely relied on linear time trends to account for changes in technology. If technology does not advance linearly, then models accounting for technology with a linear trend are misspecified and likely will contain biased coefficients.

This paper demonstrates how pooled time-series and cross-sectional data can be used to estimate the parameters of a Midwest corn acreage response function. The use of pooled data reduces the number of time-series observations that are necessary for parameter estimation. This reduction in the number of time-series observations lessens the effect of technology, and likely will eliminate the need to attempt to quantify it, as well as greatly reduce the possibility that the acreage response coefficients will change during the period under study.

Model Specification

The empirical Midwest corn acreage response model consists of time-series observations from Indiana, Illinois, Ohio, and Iowa. The model is specified in equation (1).

$$(1)\quad CA_t = f(PC_{t-1}, PS_{t-1}, GDP_t, GB_t, BIL, BOH, BIA),$$

where CA_t is state acres of corn planted in thousands of acres in year t; PC_{t-1}, state average market price of corn lagged one year in dollars per bushel; PS_{t-1}, state average market price of soybeans lagged one year in dollars per bushel; GDP_t, announced U.S. government corn diversion price times the fraction of the base corn acreage eligible for diversion in dollars per bushel (Houck et al., p. 7–15); GB_t, binary variable = 1 in years in which direct support payments were included in GDP_t (1966–73), = 0 otherwise (1963–65, 1974) (Houck and Ryan, p. 186); BIL, binary intercept shifter for Illinois; BOH, binary intercept shifter for Ohio; and BIA, binary intercept shifter for Iowa. The data consist of time-series observations on the cross-sectional units (i.e., the four states) for the years 1963 through 1974, resulting in forty-eight pooled observations.

Empirical Results

The coefficients of equation (1) were estimated with ordinary least squares (OLS). Equation (1) reflects the assumption that the acreage response to crop price change is homogeneous across the four states. Because there are large differences in corn acreage among the four states, equation (1) was estimated in a double logarithmic functional form so that the estimated acreage price elasticities would be constant across states.

Although the four-state region is relatively homogeneous, the assumption of constant corn price, soybean cross-price and corn diversion cross-price elasticities across states was tested to check the possibility of biased coefficients due to a misspecified model. Coefficient shift variables were formed for use with the lagged prices of corn, soybeans, and corn diversion. The parameters of the model in equation (1) were estimated with these coefficient (elasticity) shift variables included. The null hypothesis that all nine elasticity shift coefficients are jointly equal to zero was rejected at the .05 significance level. However, in this model, all estimated coefficient shifters were individually nonsignificant except that for Iowa corn diversion price ($IAGDP$). Equation (1) was reestimated with $IAGDP$ included. Then the null hypothesis that the other eight elasticity shift coefficients were zero

---

James K. Whittaker is an assistant professor in the Department of Agricultural and Resource Economics, Oregon State University, and Robert L. Bancroft is a research assistant in the Department of Agricultural Economics, Purdue University.

Oregon Agricultural Experiment Station Technical Paper No. 4899.

The authors wish to acknowledge the helpful comments of G. L. Nelson, R. A. Oliveira, L. F. Schrader, R. L. Thompson, and two anonymous reviewers.

was not rejected at the .05 significance level.[1] Equation (1), including *IAGDP*, was chosen as the best model. Its estimated coefficients are presented as equation (1.1) in table 1.

Previous studies by Houck et al., Wallace and Hussain, and Penn contain linear time-trend coefficients in corn acreage response equations that are two to four times the size of their standard errors. To test the need for such a measure of technology in this study, equation (1.1) was reestimated twice: once with a linear time trend included and once with the logarithm of a time trend included. Neither estimated coefficient was significantly different from zero, supporting the hypothesis that the need to include a linear time trend as a measure of technology is eliminated by shortening the time frame used for parameter estimation.

It was assumed that the error terms of the model were serially correlated, and heteroscedastic, but cross-sectionally independent.[2] Consistent estimates of the first-order serial correlation were obtained for each of the four states using the procedure described in Kmenta (pp. 509–10). The observations from Illinois exhibited significant serial correlation and were adjusted accordingly. The generated least squares estimates for model were then obtained (Kmenta, pp. 510–11).[3]

The signs on all the parameter estimates in each of the three equations are consistent with a priori expectations. The estimated coefficients in equation (1.3) are all at least twice the size of their standard errors except for soybean price. The estimated corn acreage elasticity in this study, .22 in model 1.3, is somewhat larger than estimates by Penn, Houck et al., and Ryan and Abel, which are all in the range of .12 to .17. There are several plausible explanations for this difference in elasticities. All previous studies used time-series observations beginning in the late 1940s or early 1950s, but this study used observations beginning in 1963. There is no a priori reason to assume the elasticities of acreage are constant over time.[4] Also, previous studies have estimated acreage elasticities with respect to weighted corn-price support rates, and although Houck and Ryan demonstrate that actual price lagged one year and weighted corn support price are highly correlated, some difference between acreage elasticities estimated with these two variables is to be expected. Finally, previous corn acreage response models have been linear in prices and acreages, and, therefore, elasticities were measured at the means; but the double logarithmic functional form of this study implies a constant acreage elasticity.

To test how well the transformed model fits the data, the actual and predicted acreages [from equation (1.3)] were compared. The prediction error for the region was never greater than 5%, was under 3% in all but one year, and averaged only 1.9%. In addition, the model correctly identified all four acreage turning points in 1967, 1969, 1971, and 1972.

While the final model [equation (1.3)] performs well, no claim of superiority over existing corn acreage response models using time trends is claimed. Pooling may not exhibit great advances in corn acreage response estimation, but pooled time-series and cross-sectional data are a feasible base for alternative estimates of acreage response functions, and would be particularly advantageous in response functions where technology does not advance linearly. Acreage response estimation is but one use of pooled time-series and cross-

[1] The authors realize that this significance test is based on a preliminary test, but feel the results could be enlightening.

[2] These assumptions imply that the variance of the error term differ across states (heteroscedasticity), but for a given year, the error terms of any two states are independent (cross-sectional independence).

[3] An alternative specification of the behavior of the error terms when pooled data is used is the error components model [see for example Kmenta (pp. 514–516) and Wallace and Hussain]. The error components model was not employed in this research because the necessary computer software was not available to the authors.

[4] The estimated elasticities from previous studies change by no more than .01 when calculated at mean support price and acreage for the time periods 1950–70, 1950–74, or 1963–74. In addition, the mean lagged market price-mean acreage ratio is also nearly constant for these three alternative time periods, indicating that the size of the elasticity in this study is not merely a reflection of recent high prices.

Table 1. Regressions Using the Log of Corn Acres as the Dependent Variable

Equation[a]	Constant	*ln*[b] PC_{t-1}	*ln* PS_{t-1}	*ln* *GDP*	*GB*	*BIL*	*BOH*	*BIA*	*ln* *IAGDP*	R^2
(1.1) Coefficient	8.546	0.260	−0.068	−0.096	0.065	0.667	−0.437	0.863	−0.558	.994
Standard Error	0.073	0.066	0.051	0.269	0.018	0.017	0.017	0.040	0.227	
(1.2) Coefficient	7.503	0.230	−0.013	−0.131	0.063	1.651	−0.440	0.831	−0.393	
Standard Error	0.184	0.052	0.045	0.060	0.015	0.157	0.016	0.037	0.207	
(1.3) Coefficient	7.558	0.221	−0.016	−0.147	0.071	1.604	−0.440	0.840	−0.449	
Standard Error	0.163	0.046	0.041	0.051	0.014	0.137	0.017	0.034	0.192	

[a] Equation (1.1) assumes independent and homoscedastic disturbances; (1.2) includes correction for serial correlation in Illinois, as does (1.3), and (1.3) also includes correction for heteroscedasticity in all cases.

[b] *ln* indicates natural logarithm.

sectional data. Pooling is also useful in other instances when a model includes an independent variable that changes unevenly through time and is difficult to quantify.

[*Received July 1978; revision accepted November 1978*].

References

Houck, J. P., and M. E. Ryan. "Supply Analysis for Corn in the United States: The Impact of Changing Government Programs." *Amer. J. Agr. Econ.* 54(1972):184–91.

Houck, J. P., M. E. Abel, M. E. Ryan, P. W. Gallagher, R. G. Hoffman, and J. B. Penn. *Analyzing the Impact of Government Programs on Crop Acreage*. USDA ERS Tech. Bull. No. 1548, Aug. 1976.

Kmenta, J. *Elements of Econometrics*. New York: Macmillan Co., 1971.

Penn, J. B. "Econometric Policy Models of Commodity Supply Response." Ph.D. thesis, Purdue University, 1973.

Ryan, M. E., and M. E. Abel. "Corn Acreage Response and the Set-Aside Program." *Agr. Econ. Res.* 24(1972):102–12.

Wallace, T. D., and A. Hussain. "The Use of Error Components Models in Combining Cross-Section with Time-Series Data." *Econometrica* 37(1969):55–72.

A Note on the Use of Exponential Functions for Estimating Farm Size Distributions

Bruce L. Dixon and Steven T. Sonka

Recently, considerable public and professional concern has been expressed regarding the future structure of U.S. agriculture (Doering, Barkley). These expressions of concern have considered changing features of U.S. agriculture such as concentration of production on larger units, adoption of large-scale capital intensive production technologies and rapid escalation of land prices (Raup, Klepper et al., Moles). Of course, concern about the structure of agriculture is not entirely a recent phenomenon. Price and income support legislation consistently has cited the structure of agriculture and particularly the family farm as variables of considerable importance (Spitze). Implicit in these concerns is the suspicion that changes in the structure of agriculture may have at least some attributes which are socially undesirable (Heady, Goldschmidt).

As these concerns about the future structure of agriculture are discussed, the need for processes capable of projecting that future structure intensifies. In particular, information, which addresses the question, "What will be the farm structure of the future if present forces continue?" is particularly valuable. In order to provide this information, however, the researcher needs to be able to evaluate and estimate the distribution of farm numbers across whatever measure of farm size is being utilized. This research note analyzes the regression approach to fitting an exponential function to an observed distribution as suggested by Boxley and Ching. Initially the note discusses the implied, hypothesized structural model and the use of regression for parameter estimation. Subsequently, alternative approaches are suggested and empirical comparisons presented.

The Regression Approach

Dovring (1962, 1969, 1973), Boxley, and Ching have all used exponential functions to represent farm size distributions. The studies by Boxley and Ching use a simple form of an exponential function that is easy to estimate using ordinary least squares (OLS) and frequently appears to fit the data well. Initially in this note we investigate the underlying assumptions of the Boxley and Ching model to determine the appropriate use of such a model.

Boxley and Ching employ a decumulative distribution function written as

$$(1) \qquad Y_i = Ae^{-Bx_i},$$

where Y_i is percentage of farms larger than x_i, x_i is lower limit of farm size for a given size class divided by the average farm size, e is base of the natural logarithms, and A,B are parameters.

By taking natural logarithms of (1), OLS estimates of lnA and B are obtained easily. As Ching notes, it is desirable that A and B be estimated so that $Y_i = 100$ when x_i equals its minimum value. Therefore, Ching suggests utilizing restricted least squares such that

$$(2) \qquad A = (100/e^{-Bx_1}).$$

where x_1 is the minimum farm size.

While it is not clear how Ching obtains estimates of A and B, the desired result of (2) can be obtained easily using a slight modification of OLS methods. To demonstrate this method define A as in (2) so that (1) is written as

$$(3) \qquad \begin{aligned} Y_i &= (100/e^{-Bx_1})e^{-Bx_i} \\ &= 100e^{B(x_1-x_i)}. \end{aligned}$$

Logarithms are then taken of (3) and an additive error term, u, is hypothesized for the model to obtain an OLS estimate of B from.[1]

$$(4) \qquad ln(Y_i/100) = B(x_1 - x_i) + u \; ; \; u \sim N(0, \sigma^2).$$

A problem with using (4) is that the variance of the error term is frequently heteroscedastic. The reason is that for the smaller x_i, the Y_i tend to be large. The logarithms of the Y_i associated with the smaller x_i most likely will exhibit little variation among each other relative to the logarithms of the

Bruce L. Dixon and Steven T. Sonka are assistant professors in the Department of Agricultural Economics and Rural Sociology at the University of Illinois, Urbana-Champaign.

The authors would like to thank Earl R. Swanson and John T. Scott, Jr., for a critical review of a preliminary draft. They also wish to thank Folke Dovring for stimulating their interest in the topic and for providing insights into the material.

[1] A pleasing result of this method is that A does not have to be estimated, neatly circumventing the problems of obtaining an unbiased estimate of A from the OLS estimate of lnA (see Goldberger). Furthermore, the first observation of the data requires u_1 to be zero because both the dependent and independent variables are zero. Therefore, letting there be n class sizes, the error term can only vary over $n - 1$ dimensions. Since one parameter, B, is estimated to explain the variation over the $n - 1$ dimensional space, the estimate of the variance of u has $n - 2$ degrees of freedom.

Y_i associated with the larger x_i. Thus the potential for heteroscedasticity is substantial. In such cases, of course, the OLS estimate of B, $\hat{B}$, is inefficient. Consequently, statistical inference on B becomes more complicated. For example, Ching uses a Chow test to determine if the parameters of (1) change over successive time periods. However, one of the underlying assumptions in Chow's procedure is that the error terms for all of the observations are homoscedastic.

A further complication is that the normality assumption on the error term in (4) has some curious implications. As Goldberger discusses, the normality of u implies that Y_i has a log-normal distribution. This means that the Y_i have a log-normal distribution conditional on B and x_i. Thus predictions of Y_i given x_i using (3) will be estimates of the median of Y_i and not the mean of Y_i.

Critique of Regression Approach and an Alternative Interpretation

In the above paragraphs we have suggested several reasons why OLS most likely will be a poor estimator of B; and that to ascribe some statistical properties to $\hat{B}$, a distributional assumption has to be made about the error term in (4) that has unintended implications for the predicted values of Y_i. While these problems can be patched up with a generalized least squares estimator combined with an estimator used by Goldberger, the regression approach to estimating B leads to further complications. To wit, observe that the negative of the derivative of (3) with respect to x_i is

$$\frac{-dY_i}{dx_i} = 100Be^{-B(x_i-x_1)},$$

which, when divided by 100, is simply

$$(5) \qquad = Be^{-B(x_i-x_1)}.$$

Expression (5) is the exponential density function where x_1 is a location parameter. Thus use of the functional form of (3) for a decumulative distribution function implies that the distribution of farm sizes is given by the exponential density function. In the exponential density B is the reciprocal of the mean. Because the x_i are farm sizes divided by the mean farm size, the mean of x_i is one so that B should be very close to 1.[2] To use (3) with a B different from 1 says that the population has an exponential distribution but its mean is different from what the data say it is, clearly a contradiction! A regression estimate of B different from 1 has the strong implication that (1) is a misspecification of the true distribution of farm sizes.

[2] Because the random variable is x_i less x_1, $B = 1/(1 - x_1)$. However, x_1 is likely to be very small compared to the other x_i so that for most practical purposes B can be considered equal to one.

Suppose that the researcher is willing to tolerate a misspecified model in exchange for a model that explains the variation in farm size well. Then the regression approach may be superior to specifying the population to be exponentially distributed. This latter approach requires B to be essentially one while regression approaches make no restrictions on the estimated value of B. Therefore, the regression model might possibly be superior to the exponential density in explaining variation in Y_i.

A comparison of methods demands a criterion. In their book on fitting frequency curves, Elderton and Johnson suggest that discriminating between curves on the basis of a minimum chi-square goodness-of-fit test is a plausible method. The chi-square statistic is defined as:

$$(6) \qquad \chi^2 = \sum_{i=1}^{n} [(\hat{m}_i + m_i)^2/\hat{m}_i],$$

where n is the number of classes, $\hat{m}_i$ is the number of observations predicted to be in the ith farm size class by a given model and m_i is the actual number of elements in the population that are in the ith size class. Thus chi-square is the sum of squares of observed frequency less actual frequency where each square is weighted by its expected class frequency. Additional alternative criteria could be suggested, of course, depending on the shape of the loss function for inaccurate predictions.

An Empirical Example

Some of the above ideas and problems can be explored further by examination of an empirical example. Census of Agriculture data for 1974 for farms in Illinois are used here (U.S. Bureau of the Census). The state is divided into four regions: northern, west-central, east-central and southern, which shall be referred to as areas one through four, respectively. The areas are differentiated by the predominant type of agricultural activity. Our empirical analysis is confined to comparing OLS, a maximum likelihood estimator (MLE) with u assumed heteroscedastic, and the exponential distribution. The class sizes are those given in the Census.

OLS estimates of B in (4) are shown in table 1. The null hypothesis of homoscedasticity is tested using the method of Goldfeld and Quandt. All of the F statistics are significant at the 1% level so that the hypothesis of homoskedasticity is rejected.[3] Consequently, (4) is reestimated using a maximum likelihood estimator where the variance of u_i, σ_i^2, is assumed to be $\sigma_i^2 = \sigma^2 x_i^\delta$, where δ is some positive

[3] There are twelve size classes. As discussed in footnote 1, the first observation holds no information for estimating the variance of u (and also no information of the estimate of B). Hence, the eleven observations Y_2, x_2 through Y_{12}, x_{12} are divided into two groups of five for the Goldfeld and Quandt test with Y_7, x_7 omitted.

Table 1. Regression Results for Fitting Exponential Functions

Statistics	Area 1	2	3	4
OLS estimate of B[a]	.795 (.038)	.907 (.021)	.976 (.022)	.753 (.034)
F statistic for heteroskedasticity for the OLS models[b]	1625	639.8	761.7	1529
MLE estimate of B[a]	.922 (.048)	.948 (.026)	.934 (.034)	.956 (.037)

[a] Standard errors of the estimates are in parentheses below each estimate.
[b] Significant at the 1% level.

Table 2. Chi-Square Values for the OLS, MLE, and Exponential Models of Farm Size Distribution

Model	Area 1	2	3	4
OLS	1983	1014	1480	2872
MLE	1446	863.2	1566	1121
Exponential	1496	805.8	1479	1380
Exponential with B estimated to minimize χ^2[a]	1426 (.951)	804.2 (.995)	1475 (.989)	1097 (.936)

[a] The value of B in (3) that minimizes chi-square is given in parentheses below the respective chi-square values.

number and normality is attributed to the additive error term. These estimates are given in table 1.

The chi-square statistics for MLE and OLS are given in table 2. The MLE models are clearly superior in explanatory power in three of the areas and in Area 3, where the OLS estimate is better, the margin of superiority is comparatively small. Notice that all of the MLE estimates appear to be close to one and, in terms of minimum chi-square, the OLS estimates that perform better relative to their respective MLE estimates are those closest to one. Thus OLS estimates of B substantially different from one appear to be associated with a poor explanatory model.

The third line of table 2 gives the resulting chi-square statistics for fitting the exponential density directly to the data. This is a simple matter since the population means are known. The exponential distribution fits better than OLS in all of the areas, and it is superior to MLE in two out of four areas. The superiority of the exponential over OLS is somewhat surprising since $\hat{B}$ can take on any value in the OLS model. However, the OLS estimates of B minimize the sum of squares of the logarithm of Y_i less its predicted value. Such a criterion is not closely related to explaining the variation in Y_i.[4]

To show the minimum chi-square obtainable for the exponential model (3), B was varied until a minimum was obtained. The chi-square statistics are given in the fourth line of table 2. In areas two and three the improvement over the exponential density is negligible. In area four the improvement over MLE is very slight. And in area three even OLS comes very close to the minimum chi-square. The fact that no one method is superior to the others shows simply that with varying shapes of distributions, different estimators or functional forms for different models are required.

[4] Furthermore, the coefficient of determination between $ln(Y_i/100)$ and x_i is not a good indicator of fit. For the OLS models the coefficients of determination are .961, .992, .992 and .961 and for MLE they are .921, .989, .990, and .848, respectively, for areas one through four.

The failure of any of the estimated distributions to fit the data is not surprising. Most likely no well-recognized, continuously differentiable distribution will fit the data well. In Illinois, land has been largely parceled out in 40-, 80-, 160-, etc., acre sizes due to the relatively level topography. Thus it seems quite logical that the actual distribution has many peaks, and unimodal distributions such as all of the models considered in this study will have difficulty fitting the data precisely.

Conclusions

We have brought out some of the underlying problems in using a regression approach to estimate a decumulative exponential distribution function. Because the regression approach implies an exponential density, curve fitting requires knowing only the mean of the population. This latter approach is logically consistent with the hypothesized model and is more in keeping with the traditional methods of fitting distributions to data. In terms of explanatory power the empirical examples show OLS to be generally inferior to other methods, particularly when the estimated OLS parameter is substantially different from one.

[*Received September 1978; revision accepted January 1979.*]

References

Barkley, P. W. "Some Nonfarm Effects of Changes in Agricultural Technology." *Amer. J. Agr. Econ.* 60(1978):309–15.

Boxley, R. F. "Farm Size and the Distribution of Farm Numbers." *Agr. Econ. Res.* 23(1971):87–94.

Ching, C. T. K. "A Note on the Stability of Firm Size Distribution Functions for Western Cattle Ranches." *Amer. J. Agr. Econ.* 55(1973):500–02.

Chow, G. C. "Tests for Equality between Sets of Coefficients in Two Linear Regressions." *Econometrica* 28(1960):591–605.

Doering, O. C. Appropriate Technology for U.S. Agriculture: Are Small Farms the Coming Thing? Introductory Comments." *Amer. J. Agr. Econ.* 60(1978): 293–94.

Dovring, F. "Distribution of Farm Size and Income: Analysis by Exponential Functions." *Land Econ.* 49(1973):133–47.

———. *Income and Wealth Distributions: The Exponential Functions*. Dep. Agr. Econ. AE-4212, University of Illinois, June 1969.

———. *Farm Size Data: Frequency Distribution, Interpolation and Projection*. Illinois Agr. Exp. Sta. Res. Rep. AERR-50, May 1962.

Elderton, W. P., and N. L. Johnson. *Systems of Frequency Curves*. Cambridge: Cambridge University Press, 1969.

Goldberger, A. "The Interpretation and Estimation of Cobb-Douglas Functions." *Econometrica* 36(1968): 464–47.

Goldfeld, S. M., and R. E. Quandt. "Some Tests for Homoscedasticity." *J. Amer. Statist. Assoc.* 60(1965):539–47.

Goldschmidt, W. *As You Sow*. Montclair, N.J.: Allenheld Osmun & Co., 1978.

Heady, E. O. "Externalities of American Agricultural Policy." *Toledo Law Rev.* 7(1976):795–836.

Klepper, R., W. Lockeretz, B. Commoner, M. Gertler, S. Fast, D. O'Leary, and R. Blobaum. "Economic Performance and Energy Intensiveness on Organic and Conventional Farms in the Corn Belt." *Amer. J. Agr. Econ.* 59(1977):1–12.

Moles, J. A. "Appropriate Technology for U.S. Agriculture: Are Small Farms the Coming Thing? Discussion." *Amer. J. Agr. Econ.* 60(1978):316–21.

Raup, P. M. "Some Questions of Value and Scale in American Agriculture." *Amer. J. Agr. Econ.* 60(1978):303–08.

Spitze, R. G. F. "The Food and Agriculture Act of 1977: Issues and Decisions." *Amer. J. Agr. Econ.* 60(1978):225–35.

U.S. Bureau of the Census. *Census of Agriculture, 1974*, vol. 1, part 13, State and County Data. Washington, D.C., 1977.

Perfect Aggregation Conditions for Quadratic Programming Models

N. Oguchi and A. Guccione

Sufficient conditions for the perfect aggregation of linear programming models were given by Day in 1963. Essentially the same set of conditions was shown to be necessary by Guccione and Oguchi in 1977.[1] Here we extend these results to quadratic programming systems, a natural first step in the study of consolidation for more general nonlinear programming models. We assume that the reader is familiar with Ijiri's excellent survey of the aggregation problem, aware of its general structure, and thus of its relevance to economists.

The problem under study is the following: Let the tth microsystem ($t = 1, \ldots, T$) be described by the couple of dual programs,

(1) $$\max \mathbf{p}'_t\mathbf{x}_t - (\tfrac{1}{2})\,\mathbf{x}'_t\mathbf{C}_t\mathbf{x}_t \quad \text{s.t. } \mathbf{A}_t\mathbf{x}_t \leq \mathbf{b}_t \text{ and } \mathbf{x}_t \geq \mathbf{0},$$

(2) $$\min \mathbf{b}'_t\mathbf{u}_t + (\tfrac{1}{2})\,\mathbf{x}'_t\mathbf{C}_t\mathbf{x}_t \quad \text{s.t. } \mathbf{A}'_t\mathbf{u}_t \geq \mathbf{p}_t - \mathbf{C}_t\mathbf{x}_t \text{ and } \mathbf{u}_t \geq \mathbf{0},$$

where $\mathbf{C}_t$ is a positive semidefinite matrix, and where all terms are defined as in Van de Panne's well-known textbook (pp. 261–96). Let the corresponding macrosystem ($t = 0$) be specified by the relations

(3) $$\mathbf{p}_o = \sum_{t=1}^{T} \alpha_t\mathbf{p}_t,\ \mathbf{C}_o = \sum_{t=1}^{T} \alpha_t\mathbf{C}_t,$$

$$\mathbf{A}_o = \sum_{t=1}^{T} \beta_t\mathbf{A}_t,\ \mathbf{b}_o = \sum_{t=1}^{T} \mathbf{b}_t,$$

where the (arbitrary) weights α_t and β_t must satisfy the restrictions

$$\alpha_t, \beta_t \geq 0,\ \sum_{t=1}^{T} \alpha_t = \sum_{t=1}^{T} \beta_t = 1.$$

We wish to investigate which conditions must be imposed on the matrices $\mathbf{A}_t$ to satisfy, for (conveniently restricted sets of) all values of the matrices $\mathbf{p}_t$, $\mathbf{C}_t$, and $\mathbf{b}_t$, the relations

(4) $$\mathbf{x}^*_o = \sum_{t=1}^{T} \mathbf{x}^*_t \text{ and } \mathbf{y}^*_o = \sum_{t=1}^{T} \mathbf{y}^*_t,$$

(5) $$\mathbf{u}^*_o = \sum_{t=1}^{T} \alpha_t\mathbf{u}^*_t \text{ and } \mathbf{v}^*_o = \sum_{t=1}^{T} \alpha_t\mathbf{v}^*_t,$$

where $\mathbf{y}_t$ and $\mathbf{v}_t$ are, respectively, primal and dual slack variables, and where the starred variables indicate optimal solutions to the systems (1) and (2) ($t = 0, 1, \ldots, T$). That is, the starred variables satisfy the Kuhn-Tucker conditions

(6) $$\mathbf{A}_t\mathbf{x}_t + \mathbf{y}_t = \mathbf{b}_t,$$

(7) $$\mathbf{A}'_t\mathbf{u}_t - \mathbf{v}_t = \mathbf{p}_t - \mathbf{C}_t\mathbf{x}_t,$$

(8) $$\mathbf{u}'_t\mathbf{y}_t + \mathbf{v}'_t\mathbf{x}_t = \mathbf{0}, \text{ and}$$

(9) $$\mathbf{x}_t, \mathbf{y}_t, \mathbf{u}_t, \mathbf{v}_t \geq \mathbf{0}.$$

We note immediately that unconstrained, perfect aggregation is obviously impossible, and that therefore restrictions must be imposed on the domains of the exogenous variables $\mathbf{p}_t$, $\mathbf{C}_t$, $\mathbf{b}_t$. That is, in terms of Ijiri's useful classification scheme, "constrained consistency" rather than "total consistency" is relevant here. As is well known, the choice of appropriate subsets of the exogenous variables' domains is in general not unique. In practice, a balance must be struck between the empirical relevance of the restrictions imposed and the generality of the results obtained. We assume, first, that all matrices $\mathbf{p}_t$, $\mathbf{C}_t$, $\mathbf{b}_t$ are equal over the microsystems. Although this choice is restrictive, "it may be appropriate for firms, especially in circumstances in which quasi-linearity is also appropriate" (Lancaster, pp. 213–14). Second, we constrain the exogenous variables to those values which imply the same pattern of zeros in all the optimal solutions (a more transparent, geometric interpretation of this condition will be given below). The implications of these two restrictions are summarized in the following propositions.

PROPOSITION 1. *Perfect aggregation of the primals is possible if, and only if, all matrices $\mathbf{A}_t$ ($t = 1, \ldots, T$) are equal.*

Proof. Notice that if $\mathbf{A}_t = \mathbf{A}$, $\mathbf{b}_t = \mathbf{b}$ ($t = 1, \ldots, T$), then $\mathbf{A}_o = \mathbf{A}$ and $\mathbf{b}_o = T\mathbf{b}$. Let the vectors $(\mathbf{x}_o, \mathbf{y}_o)$ be a solution to equation (6) for the macrosystem, then the vectors $(\mathbf{x}, \mathbf{y}) = T^{-1}(\mathbf{x}_o, \mathbf{y}_o)$ solve (6) for the

---

Noriyoshi Oguchi is an associate professor, and Antonio Guccione is a professor of economics, University of Windsor, Canada.

Helpful comments by W. J. Gillen and an anonymous reviewer of an earlier draft of this paper are gratefully acknowledged.

[1] A number of interesting papers should be mentioned here, in particular those by Miller, Lee, and Marenco. In addition, Paris and Rausser have derived a set of sufficient conditions which depend on endogenously determined (rather than arbitrarily fixed) aggregation weights.

microsystem. If the solution $(\mathbf{x}_o, \mathbf{y}_o)$ is optimal, by the second restriction on the exogenous variables, $T^{-1}(\mathbf{x}_o, \mathbf{y}_o)$ must also be optimal.

To prove necessity, consider the special (but permissible) case in which $\mathbf{C}_t = \mathbf{0}$ for $t = 1, \ldots, T$. Then the requirement of equal technologies can be obtained immediately from the necessary conditions for the linear-programming case (see Guccione and Oguchi).

Remark

We can now discuss the second constraint on the exogenous variables. Assume we know the optimal macrosolutions $(\mathbf{x}^*_o, \mathbf{y}^*_o)$ and $(\mathbf{u}^*_o, \mathbf{v}^*_o)$. What restrictions must be imposed on the matrices $\mathbf{p}_t, \mathbf{C}_t, \mathbf{b}_t$ (in addition to equality over microunits), to obtain the same pattern of zero entries in the optimal microsolutions $(\mathbf{x}^*, \mathbf{y}^*)$ and $(\mathbf{u}^*, \mathbf{v}^*)$? The vectors $(\tilde{\mathbf{x}}, \tilde{\mathbf{y}}) = T^{-1}(\mathbf{x}^*_o, \mathbf{y}^*_o)$ satisfy both equations (6) and the two first inequalities in (9) and display the property desired. Let the pattern of zeros in equation (8) be the same at both levels of consolidation. If the dual solution $(\tilde{\mathbf{u}}, \tilde{\mathbf{v}})$, defined by setting the right-hand side of equation (7) equal to $(\mathbf{p} - \mathbf{C}T^{-1}\mathbf{x}^*_o)$, and choosing the zero entries as in (8), were to satisfy the last two conditions in (9), $(\tilde{\mathbf{x}}, \tilde{\mathbf{y}}) = (\mathbf{x}^*, \mathbf{y}^*)$ and $(\tilde{\mathbf{u}}, \tilde{\mathbf{v}}) = (\mathbf{u}^*, \mathbf{v}^*)$. But then, the relevant question is whether any change in signs takes place in the solution of equation (7). There will be no change if, and only if, both $(\mathbf{p} - \mathbf{C}\mathbf{x}^*_o)$ and $(\mathbf{p} - \mathbf{C}T^{-1}\mathbf{x}^*_o)$ lie in the cone spanned by the columns of the matrix $(\mathbf{A}' - \mathbf{I})$. In practice, this condition can be detected only by means of post-optimality analysis. That is, having solved the primal macroproblem, parametric programming must be performed on the right-hand-side constants of the constraints, and the solutions compared.

PROPOSITION 2. *Perfect aggregation of the duals is, in general, impossible.*

Proof. From the first relation in (3) and the main dual constraints we obtain

$$\mathbf{A}'_o\mathbf{u}^*_o - \mathbf{v}^*_o + \mathbf{C}_o\mathbf{x}^*_o = \sum_{t=1}^{T} \alpha_t\mathbf{A}'_t\mathbf{u}^*_t - \sum_{t=1}^{T} \alpha_t\mathbf{v}^*_t + \sum_{t=1}^{T} \alpha_t\mathbf{C}_t\mathbf{x}^*_t,$$

or, since $\mathbf{A}_t = \mathbf{A}$, $\mathbf{C}_t = \mathbf{C}$, $\mathbf{x}^*_o = T\mathbf{x}^*$,

$$\mathbf{A}'\left(\mathbf{u}^*_o - \sum_{t=1}^{T} \alpha_t\mathbf{u}^*_t\right) - \left(\mathbf{v}^*_o - \sum_{t=1}^{T} \alpha_t\mathbf{v}^*_t\right) = \left(\sum_{t=1}^{T} \alpha_t\mathbf{C}\mathbf{x}^*_t - \mathbf{C}T\mathbf{x}^*\right).$$

For perfect aggregation of the dual variables [see equation (5)], it is required that the right-hand-side expression be null. That is, after some obvious manipulations and premultiplication by the vector $(\mathbf{x}^*_o)'$,

$$(1 - T)(\mathbf{x}^*_o)'\mathbf{C}\mathbf{x}^*_o = 0.$$

But this equation holds only in two special cases: when the number of units to be aggregated is one, and when the systems considered are essentially linear.

Ijiri's discussion of constrained aggregation (pp. 771–72) seems to imply the following research strategy. First, the problem should be shown intractable in unrestricted form and the exogenous variables conveniently constrained. Then, the possibility of extending their domains should be tested. With reference to the last stage, we conjecture that, for the given aggregation framework, additional research efforts would be met by rapidly declining returns. However, progress is possible if the aggregation weights are allowed to be endogenous.[2]

[*Received February 1978; revision accepted January 1979.*]

References

Day, Richard H. "On Aggregating Linear Programming Models of Production." *J. Farm Econ.* 45(1963):797–813.

Guccione, Antonio, and Noriyoshi Oguchi. "A Note on the Necessary Conditions for Exact Aggregation of Linear Programming Models." *Math. Programming* 12(1977):133–35.

Ijiri, Yuji. "Fundamental Queries in Aggregation Theory." *J. Amer. Statist. Assoc.* 66(1971):766–82.

Lancaster, Kelvin. "Economic Aggregation and Additivity." *The Structure of Economic Science*, ed. Sherman R. Krupp. Englewood Cliffs, N.J.: Prentice-Hall, 1966.

Lee, John E. "Exact Aggregation. A Discussion of Miller's Theorem." *Agr. Econ. Res.* 18(1966):58–61.

Marenco, Gaetano. "Exact Aggregation with Linear Programming Models. A Note on the Sufficient Conditions Proposed by R. H. Day." *Amer. J. Agr. Econ.* 51(1969):684–86.

Miller, Thomas A. "Sufficient Conditions for Exact Aggregation in Linear Programming Models." *Agr. Econ. Res.* 18(1966):52–57.

[2] As an interesting example, let the aggregation weights for the matrices $\mathbf{C}_t$ be all equal to T^{-2}, all other weights being defined as in the text. Then, if the exogenous variables and the technologies are equal (over microunits), we have

$$\begin{aligned}\mathbf{p} - \mathbf{C}_o\mathbf{x}^*_o &= \mathbf{p} - \mathbf{C}T^{-1}\mathbf{x}^*_o \\ &= \mathbf{p} - \mathbf{C}T^{-1}T\mathbf{x}^* \\ &= \mathbf{p} - \mathbf{C}\mathbf{x}^*.\end{aligned}$$

That is, no post-optimality analysis is required and the microsystems can be aggregated. For this approach to consolidation, in the context of mathematical programming, see the paper by Paris and Rausser.

The Factor Share Approach to Production Function "Estimation": Actual or Estimated Equilibrium Shares?

C. Richard Shumway, Hovav Talpaz, and Bruce R. Beattie

For years agricultural economists have been concerned with obtaining reliable estimates of production function parameters. Among other reasons, such estimates are needed to address policy issues involving resource misallocation, supply response, and factor demand in agriculture. The appeal of production function approaches to such problems, as contrasted with direct estimation of product supply and factor demand relationships, is with the richness of the model for addressing cross-price effects and matters of resource allocation.

However, as is well known, problems of multicollinearity and technological change have thwarted most efforts to obtain reliable estimates of aggregate production elasticities by direct estimation (Doll; Rosine and Helmberger). In an effort to circumvent the multicollinearity barrier posed by direct estimation, Tyner and Tweeten (1965) indirectly estimated aggregate production elasticities for U.S. agriculture using a factor share approach. Noting that in equilibrium, factor shares equal factor elasticities for an industry comprised of profit-maximizing firms, Tyner and Tweeten synthesized a Cobb-Douglas production function by estimating equilibrium factor shares based on historical data and the Nerlove partial adjustment model. Equilibrium factor shares were estimated individually for each of nine input categories assuming that actual adjustment between any two years was a constant proportion of the extent of own-factor disequilibrium. Estimates were developed for several decades by including dummy variables in the model. In a subsequent article Tyner and Tweeten (1966) developed estimates of resource misallocation, product supply elasticity, and factor demand elasticities based on their indirectly estimated Cobb-Douglas production functions.

In 1974 Rosine and Helmberger published an article with a similar intent. They also explored several macro policy issues based on a synthesized Cobb-Douglas production function for U.S. agriculture. They used a simpler model than Tyner and Tweeten, by assuming that production elasticities were given by actual factor shares. In effect, Rosine and Helmberger assumed instantaneous adjustment to equilibrium thereby avoiding numerous estimation difficulties. (See writings of D. Gale Johnson in 1948 and Ruttan and Stout in 1960 for examples of earlier expressions of interest in factor shares.)

To develop normative estimates of production elasticities following a factor share approach, it seems clear, a priori, that the Tyner-Tweeten approach should be preferable conceptually to that of Rosine and Helmberger. In the words of Tyner and Tweeten, "the use of [actual] factor shares as production elasticities trades the intercorrelation problem for the dubious assumption that economic equilibrium prevails" (1965, p. 1462). The purpose of this paper is to evaluate the practical effects of the assumption of continual economic equilibrium (instantaneous adjustment) on production elasticity estimation.

In the following section the Rosine-Helmberger and Tyner-Tweeten factor share approaches are briefly reviewed. We then examine empirical results from a refitting of Tyner and Tweeten's factor share adjustment model, using 1910–76 data to ascertain the extent to which predicted equilibrium factor shares deviate from actual factor shares, the Rosine-Helmberger approach. The paper concludes with some recommendations for further research on production function estimation in terms of both direct and indirect (factor share) approaches.

Two Alternative Factor Share Adjustment Approaches

While no rigorous theory of factor share adjustment has been suggested in prior literature, a connection can be made with the neoclassical theory of the firm. An industry comprised of profit-maximizing, perfectly competitive firms is in equilibrium when the partial production elasticities equal their factor shares, i.e.,

$$(1)\qquad (\partial y/\partial x_i)(x_i/y) = r_i x_i/py,$$

where y is product quantity, x_i is quantity of factor i, and r_i and p are factor and product prices, respectively. The left side of (1) is the elasticity of output

---

C. Richard Shumway, Hovav Talpaz, and Bruce R. Beattie are associate professors of agricultural economics, Texas A&M University. Hovav Talpaz is concurrently at the Department of Statistics, The Volcani Center, Israel.

Texas Agricultural Experiment Station Technical Article No. 14734.

The authors express appreciation to Bruce Gardner, John Penson, and Robert Taylor for many helpful comments on this paper, and to Fred Tyner and Luther Tweeten for sparking their interest in the subject. The authors also thank Don Durost for providing and interpreting unpublished U.S. Department of Agriculture data used in this study.

with respect to factor use. The right side is the factor share, which in equilibrium is denoted F^*_i.

As technological and economic conditions change, the optimal quantities of y supplied and x_i demanded change and so, therefore, does F^*_i. Because prices fluctuate widely and technology changes over time, producers operate in both an uncertain and temporal world. Actual factor share (F_i) is simply a manifestation of producer decisions implied by equation (1). Because of uncertainty and the fact that it takes time to adjust fully to a new set of technical or economic circumstances, F_i is likely not the same as the unobserved F^*_i. That, in effect, was the Tyner-Tweeten hypothesis.

The Rosine-Helmberger approach represents the ultimate in simplification; equilibrium is assumed and actual factor shares are taken as estimates of the production elasticities. Adding the time subscript t to our notation, Rosine and Helmberger implicitly assume that $F^*_{i,t} \equiv F_{i,t}$. That is, instantaneous and complete adjustment of all factor shares is assumed so that the system is continually in equilibrium. The simplicity of the Rosine-Helmberger approach is appealing because no estimation is required. This procedure assumes that actual factor share is equilibrium share, i.e., no deviation is postulated.

Tyner and Tweeten, on the other hand, rejected the assumption of instantaneous adjustment or continuous equilibrium. Dropping the subscript i for the moment, they hypothesized an adjustment model for each factor share of the form

$$(2) \qquad F_t - F_{t-1} = \gamma(F^*_t - F_{t-1}),$$

where γ is the proportion of adjustment accomplished during period t, $0 < \gamma \leq 1$. This equation was expressed in stochastic form as

$$(3) \qquad F_t = \beta_0 + \beta_1 F_{t-1} + e_t,$$

where $\beta_0 = \gamma F^*_t$ and $\beta_1 = 1 - \gamma$. Implied equilibrium factor share, $\beta_0/(1 - \beta_1)$, was postulated to change from decade to decade by including zero-one dummy variables (D) on the intercept, i.e., $\beta_0 = \beta'_0 + \sum_{k=1}^{K} d_k D_k$. Using this model, its logarithmic form, and their autoregressive counterparts, Tyner and Tweeten estimated equilibrium factor shares for nine individual input categories for five different decades $(K = 4)$.

Comparison of Estimated Equilibrium Factor Shares with Actual Factor Shares

Data for the comparative analysis are from published and unpublished USDA sources as were Tyner-Tweeten's and Rosine-Helmberger's. Estimates are developed for eight farm input categories based on annual U.S. data 1910–76. (Tyner and Tweeten's data were from 1910 to 1961; Rosine and Helmberger's, 1948–70.) Our input categories are similar to Tyner and Tweeten's; we have one less category, as real estate taxes are combined with other real estate expenses.[1]

Average factor shares (actual) over each of six decades and estimated equilibrium factor shares following Tyner and Tweeten's partial adjustment approach are presented in table 1. The partial adjustment estimates were obtained by fitting the following equation for each input

$$(4) \qquad F_t = \beta'_0 + \sum_{k=1}^{5} d_k D_k + \beta_1 F_{t-1} + e_t.$$

Equations in which the lagged dependent variable appears as an explanatory variable frequently exhibit serially correlated disturbance terms and also bias the test for serial correlation in ordinary least squares (OLS) estimation. Consequently, the less restrictive Cochrane-Orcutt model with Cooper's transformation was used to obtain parameter estimates and standard errors with asymptotically desirable properties for these equations.

From table 1 we first notice that all the estimated equilibrium factor shares are, not surprisingly, of the right sign and significantly different from zero at typically acceptable significance levels. The R^2 values ranged from .81 to .94. However, more interesting is the small (in many cases, negligible) difference between the estimated equilibrium factor share and the mean actual factor share for each input for each decade. All of the decade-mean actual factor shares fall within a 90% confidence interval about the estimated equilibrium; 98% fall within a 75% confidence level.[2]

The average percentage difference between estimated equilibrium and actual factor shares is less than 6%. For only eight of the fifty-four comparisons does the percentage difference exceed 10%. The greatest differences are for machinery investment and machinery operating expenditures in the first and postwar decades. Clearly these results do not provide persuasive evidence to conclude that equilibrium factor shares, assumed constant over a decade, differ substantially from average actual factor shares. That is, our empirical results do not provide a basis for rejecting the hypothesis of Rosine and Helmberger (pp. 718–19), *viz.*, that the

[1] Most data used in this paper are from July 1977 *Farm Income Statistics* (USDA, 1977) and from July 1957 and July 1965 *Farm Income Situation* (USDA, 1957, 1965) with appropriate supplementation and adjustment. Some additional expense items are included in a number of the input categories that were not included in Tyner and Tweeten's data. Details concerning data development and sources are available on request from the authors. Factor share for any category consists of actual expenditures on that category divided by farm income for the same year.

[2] The test employed is an approximation. Exact tests require knowledge of the variance-covariance matrix. We know the variance of each and that there is a nonzero covariance, but we do not know the magnitude of the covariance. Therefore, our test is conducted computing a confidence interval around the estimated equilibrium to see if the actual factor share falls within it. We realize that actual factor share is not an arbitrary value but is also a random variable, and we are not considering either its variance or its covariance with the estimated equilibrium.

Table 1. Decade Average Factor Shares and Partial Adjustment Equilibria Estimates for U.S. Agriculture, 1911–76

		Factor Share by Decade					
Input Category	R^2	1911–26	1927–36	1937–46	1947–56	1957–66	1967–76
		%					
1. Fertilizer and lime	.87	2.29[a]	2.39	2.64	3.21	4.16	5.22
		2.28[b]	2.47	2.57	3.35	4.30	5.40
		(.27)[c]	(.35)	(.34)	(.35)	(.34)	(.35)
2. Feed, seed, and livestock	.94	2.83	3.46	4.30	5.42	5.78	5.66
		2.98	3.54	4.39	5.60	5.85	5.57
		(.17)	(.24)	(.24)	(.24)	(.23)	(.23)
3. Labor	.81	41.67	42.48	41.80	36.60	32.08	27.71
		40.92	42.52	41.89	35.49	31.79	26.85
		(2.22)	(1.59)	(2.42)	(2.61)	(2.25)	(2.52)
4. Machinery investment	.91	5.15	7.84	5.95	9.13	12.08	12.53
		5.69	7.98	5.19	11.22	11.86	13.35
		(1.14)	(1.27)	(1.43)	(2.04)	(1.26)	(1.38)
5. Real estate	.85	32.10	30.71	16.06	15.86	23.80	29.06
		31.02	29.40	15.66	17.10	24.21	30.34
		(2.89)	(3.27)	(3.34)	(3.29)	(3.30)	(3.37)
6. Machinery operating	.94	2.14	5.50	5.70	7.79	8.49	6.77
		3.14	6.16	5.53	9.50	7.60	6.91
		(.93)	(1.06)	(.96)	(1.46)	(1.12)	(.97)
7. Miscellaneous operating	.91	5.05	6.29	4.83	5.22	8.48	9.27
		4.94	6.39	4.36	5.97	8.79	9.54
		(.66)	(.75)	(.89)	(.94)	(.82)	(.78)
8. Crop and livestock inventory	.90	5.04	4.76	4.22	3.94	3.69	3.39
		4.95	4.79	4.08	3.82	3.66	3.23
		(.15)	(.19)	(.22)	(.21)	(.20)	(.23)
Total		96.27	103.43	85.50	87.17	98.56	99.61
		95.92	103.25	83.67	92.05	98.06	101.19

[a] Actual values of factor shares.
[b] Estimated equilibrium values of factor shares.
[c] Approximate standard errors (in parentheses) of estimated equilibria are obtained from

$$SE_{\hat{r}_k} = SE\left(\frac{\hat{\beta}'_0 + \hat{a}_k}{1 - \hat{\beta}_1}\right) \approx \frac{\hat{\beta}'_0 + \hat{a}_k}{1 - \hat{\beta}_1}\left\{\frac{\mathrm{Var}(\hat{\beta}'_0) + \mathrm{Var}(\hat{a}_k) + 2\mathrm{Cov}(\hat{\beta}'_0,\hat{a}_k)}{(\hat{\beta}'_0 + \hat{a}_k)^2} + \frac{\mathrm{Var}(\hat{\beta}_1)}{(1 - \hat{\beta}_1)^2} + 2\left[\frac{\mathrm{Cov}(\hat{\beta}_1,\hat{\beta}'_0) + \mathrm{Cov}(\hat{\beta}_1,\hat{a}_k)}{(\hat{\beta}'_0 + \hat{a}_k)(1 - \hat{\beta}_1)}\right]\right\}^{\frac{1}{2}}$$

for the model in equation (4).

assumption, "in each year, the price of an input is equated to its value of marginal product," is tolerably close to the real world.

Accordingly we conclude that if one is going to develop normative estimates of factor elasticities using factor shares as proxies (following either Rosine-Helmberger or Tyner-Tweeten), the most cost-effective research procedure is simply to use actual factor shares for the year(s) of interest. The extent of disequilibrium appears generally to be insufficient to justify effort in estimating equilibrium factor shares, at least for the case of aggregate U.S. agriculture. This finding may be due to either of two possibilities: (*a*) disequilibrium is minor; or (*b*) if disequilibrium is significant, the Tyner-Tweeten partial adjustment model and estimation technique is not sophisticated enough to detect it.[3]

Some Thoughts on Further Research

Other autoregressive alternatives to the Tyner-Tweeten model have been developed by the authors to overcome some of its restrictive assumptions. Empirical results consistent with those reported in this paper were obtained.[4] However, none of these

[3] When estimated equilibrium factor shares are very close to actual and actual prices are used to derive the minimum cost allocation of resources, the implied misallocation is small (Shumway, Beattie, Talpaz).

[4] Two restrictive assumptions of the Tyner-Tweeten model are (*a*) equilibrium factor share is constant over a decade, and (*b*) only the previous and current years' factor shares influence equilibrium factor share in the current time period. The authors developed an autoregressive integrated moving average (ARIMA) model in an attempt to come to grips with these shortcomings, although not accounting for the simultaneous effects of adjustments in all factor shares. The empirical results did not differ in important ways from those of the Tyner-Tweeten model. Fully 91% of actual annual factor shares fell within a 90% confidence interval about the estimated equilibrium; 80% were within a 75% interval. Additionally, previous work applying a polynomial lag adjustment model to the

models accounts for the simultaneity in factor share adjustment that seems obvious on a priori grounds. Since a particular factor share (F_i) is the ratio of expenditure on that factor to total receipts from output produced, a change in expenditure on any other factor, due to a change in its price or technology, indirectly causes a change in F_i. This occurs because the change in a factor's price or technology directly affects its quantity purchased, the quantity of output produced, and, no doubt, total receipts. Clearly, adjustments in individual factor shares and/or factor quantities are not made independently of other factors.

If specification bias due to simultaneity is a serious problem in the Tyner-Tweeten model, it seems unlikely that additional research effort directed toward more completely specified models of factor share adjustment will be fruitful. There is multicollinearity in the factor share data just as there is in the input expenditure data that one would use to estimate production coefficients directly. In fact, for the period of study, the correlation in the factor share data was nearly as great as in the expenditure data, to say nothing of the correlation present in the lagged factor share data. The principal justification for looking to the normative factor share approach in the first place was avoidance of multicollinearity associated with direct estimation. Yet, more elaborate factor share adjustment models formally recognizing factor share interdependencies would be plagued by the same problem in addition to some others.

Conclusion

Relevant options for estimating production coefficients appear to be limited to two major alternatives: (*a*) use of actual factor shares and (*b*) direct positive estimation. Normative estimation based on historical factor share data and fully specified models is fraught with econometric difficulties rivaling those of direct estimation. Further, abbreviated versions of fully specified factor share adjustment models, like Tyner and Tweeten's, do not reveal sufficient disequilibria to substantiate effort in their estimation. Thus, if the factor share approach is followed, the least-cost research alternative of assuming instantaneous and complete adjustment, i.e., using actual factor shares, seems appropriate.

[*Received November 1978; revision accepted March 1979.*]

Tyner-Tweeten data gave decade-average equilibrium estimates that generally were also very close to actual factor shares (Shumway, Talpaz, Beattie).

References

Cochrane, D., and G. H. Orcutt. "Application of Least Squares Regression to Relationships Containing Autocorrelated Error Terms." *J. Amer. Statist. Assoc.* 44(1949):32–61.

Cooper, J. P. "Asymptotic Covariance Matrix of Procedures for Linear Regression in the Presence of First-Order Autoregressive Disturbances." *Econometrica* 40(1972):305–10.

Doll, J. P. "On Exact Multicollinearity and the Estimation of the Cobb-Douglas Production Function." *Amer. J. Agr. Econ.* 56(1974):556–63.

Rosine, J., and P. Helmberger. "A Neoclassical Analysis of the U.S. Farm Sector, 1948–1970." *Amer. J. Agr. Econ.* 56(1974):717–29.

Shumway, C. R., B. R. Beattie, and H. Talpaz. "Optimum Resource Allocation in U.S. Agriculture: Comment." *Amer. J. Agr. Econ.* 59(1977):778–83.

Shumway, C. R., H. Talpaz, and B. R. Beattie. *Resource Allocation in U.S. Agriculture: Application of an Improved Polynomial Lag Estimation Procedure.* Texas Agr. Exp. Sta. Dep. Tech. Rep. 77-6, Apr. 1977.

Tyner, F. H., and L. G. Tweeten. "A Methodology for Estimating Production Parameters." *J. Farm Econ.* 47(1965):1462–67.

———. "Optimum Resource Allocation in U.S. Agriculture." *J. Farm Econ.* 48(1966):613–31.

U.S. Department of Agriculture. *Farm Income Statistics.* ERS Statist. Bull. 576, July 1977.

———. *Farm Income Situation.* Econ. Res. Serv. July 1957, July 1965.

On Agricultural Productivity Differences among Countries

Dũng Nguyen

The sources of agricultural productivity differences among countries have been examined extensively by Professors Hayami and Ruttan in their important work published in 1971 (Hayami and Ruttan, chap. 5. See also their 1970 article.) Their method involved the estimation of an aggregate agricultural production function based on intercountry cross-section data for the period centered on 1960, using average per farm data and national aggregate data separately. Further, that study involved the estimation of the per worker production function where data for the years 1955 (1952–56 averages), 1960, and 1965 (1962–66 averages) were used either separately or pooled. The estimation with the pooled samples enabled Hayami and Ruttan to test the stability of the agricultural production function over the 1955–60–65 period using the analysis of covariance method.

The main motivations for the present study are as follows: (*a*) the latest data used in the Hayami-Ruttan work were those for 1965. It is, therefore, of empirical interest to incorporate into the analysis the more recent information. (*b*) In an effort to gain more meaningful interpretations of the impact of education (general and technical) on agricultural productivity, we are interested in using certain proxy variables for education which are different from those of Hayami and Ruttan. (*c*) One of the important results obtained by Hayami and Ruttan was that the agricultural production parameters are stable during the 1955–60–65 period. Our attempt to include the 1970 and 1975 data naturally would require additional tests for the stability of the production function because the behavior of the 1970 and 1975 functions may differ from those of the previous years. (*d*) We intend to analyze the stability question more intensively by examining the differences not only in the intercepts of the production functions but also in their regression coefficients.

The objective of this study is thus twofold: first, to estimate the agricultural production function using the data for 1970 (1968–72 averages) and for 1975 (1974–76 averages), the estimation is made using the per capita as well as the national aggregate data; second, to test the stability of the agricultural production function over time using the 1955, 1960, 1965, 1970, and 1975 intercountry cross-section sample.

The Theoretical Framework

For ease of reference, let us state below the form of the agricultural production function as specified by Hayami and Ruttan:

$$(1) \qquad Y = e^{\alpha_1} N^{\alpha_2} A^{\alpha_3} L^{\alpha_4} F^{\alpha_5} M^{\alpha_6} GE^{\alpha_7} TE^{\alpha_8},$$

where Y is agricultural output; N, the number of male workers in agriculture; A, the agricultural land area; L, the livestock; F, the fertilizer consumption; M, the tractor horsepower; GE, the general education level; and TE, the technical education level. Units of measure for all preceding variables are given in the next section.

Equation (1) describes the familiar unrestricted Cobb-Douglas production function. Theoretical justifications for this representation were given in the original work of Hayami and Ruttan. It can be noted that in the present cross-section framework, the existence of the function in (1) implies that all countries are assumed to operate along a common production function. This may not be a sound assumption because the sample consists of various countries with clearly different degrees of economic backwardness. Here we will counter this argument by taking the Hayami-Ruttan position that, while working with the specification in (1), one implicitly assumes the existence of a meta-production function along which technical change would take place in response to changes in relative prices of the production factors. For further discussions on this and related issues, the reader is referred to papers by Griliches, Krueger, and Nelson.

The Stability of the Agricultural Production Function

Covariance analysis has been discussed at considerable length by Johnston (pp. 192–207). Assuming that many results related to this topic are well known to the reader, we wish to make a number of observations as follows: (*a*) The variance analysis appearing in the Hayami-Ruttan work was based

Dũng Nguyen is a doctoral candidate in the Department of Economics, University of Maryland.

An earlier version of this paper was completed while the author was a senior lecturer in economics at the University of the Philippines, School of Economics. He wishes to thank Professors Randolph Barker, Yujiro Hayami, Robert Herdt, and the reviewers of the *Journal* for their encouragement and many helpful comments.

only on the "overall effect" category. (*b*) The "overall effect" represents essentially the Chow test of equality between two sets of regression coefficients (Chow, Fisher). (*c*) The statistical foundation is described adequately in the text by Johnston. However, his "practical procedures" to carry out covariance tests may not prove to be the most efficient. We can obtain the desired results in a much simpler way when viewing the covariance analysis as a linear-restriction problem. However, due to the familiarity of the conventional covariance analysis, we will follow these procedures throughout this paper, while leaving the linear-restriction alternative to the interested reader.

Sources of Data

Data for agricultural output Y, in thousand wheat units, were obtained by extrapolation from those in the Hayami-Ruttan book with the FAO country index numbers of total agricultural production (*FAO Production Yearbook, UN Statistical Yearbook*). The International Labor Office's *Yearbook of Labor Statistics* is the source of data for male employment in agriculture, forestry, hunting, and fishing. Number of male workers in agriculture N, in thousands, is then derived by using the weighting factors provided in the Hayami-Ruttan book. Agricultural land area A, in thousand hectares, is the sum of arable land, land under permanent crops, and permanent meadows and pastures. Data for A are given in the *FAO Production Yearbook.* Data for livestock L, in thousand units, can be found in the *UN Statistical Yearbook.* The figures used in our analysis are five-year averages and three-year averages centered on 1970 and 1975, respectively, after the original data were converted to livestock units by the weights suggested by Hayami and Ruttan. The same UN source also gives data for fertilizer consumption F, in thousand metric tons. Data for tractor horsepower M, in thousand units, are obtained from the *FAO Production Yearbook.* We adopted the Hayami-Ruttan method in computing horsepower units by giving thirty horsepower for a farm tractor and five horsepower for a garden tractor. All figures for F and M are either five-year averages centered on 1970, or three-year averages centered on 1975. The level of general education is measured using two alternatives. General education 1 ($GE1$) refers to the gross enrollment ratio for the primary and secondary levels, whereas that for the secondary levels defines general education 2 ($GE2$). The latter is our newly suggested alternative for a measure of general knowledge. Data for both $GE1$ and $GE2$ can be found in the *UNESCO Statistical Yearbook.* Finally, a proxy variable for technical education (TE) is defined to be the number of graduates from agricultural colleges per ten thousand male farmers. Data for these variables are also obtainable from the *UNESCO Statistical Yearbook.*

Thus, except for $GE2$, all variables are defined exactly in the same manner as originally suggested by Hayami and Ruttan. However, we will be able to point out later that our attempt to redefine another explanatory variable turns out to be empirically unsuccessful. For the regressions on the years 1955, 1960, and 1965, all data in the Hayami-Ruttan book are used.

The Empirical Results and the Analysis

Results of the estimation of the agricultural production function (1) expressed in log form are reported in table 1 for the separate samples of 1970 and 1975, as well as the pooled sample of the period 1955–60–65–70–75. The functions are estimated using only the national aggregate data because Hayami and Ruttan have pointed out that the estimation using the average per farm data did not lead to different results concerning the regression coefficients.

Columns 2 and 3 include the estimation of the production function parameters for the year 1970. It can be observed that the alternative measures of the level of general education as represented by $GE1$ and $GE2$ lead to different results regarding the contribution of general knowledge to the agricultural production process. While the coefficients associated with $GE1$ in column 2 is not statistically different from zero, that corresponding to $GE2$ is statistically greater than zero (at the 80% confidence level). As it turns out, not only for the period of 1970 but for every period running from 1955 to 1975, the variable $GE2$, as compared to $GE1$, proves to be the better measure for general education in the sense that it is capable of producing a meaningful relationship between agricultural productivity of various countries and levels of general knowledge of their respective population. This fact can be understood by recalling the definitions of $GE1$ and $GE2$. It can be argued that, in contrast to smaller variations in the enrollment ratios for the primary and secondary levels among countries, variations in the enrollment ratios for the secondary levels are sufficiently large to be able to explain a significant contribution of general education to agricultural productivity.

Another feature to be noted from columns 2 and 3 is that the 1970 production function still exhibits the characteristic of constant returns to scale. This result was obtained earlier by Hayami and Ruttan for the data of 1955, 1960, and 1965. As we will see, this also remains to be the characteristic for the 1975 agricultural production function.

The coefficients of all conventional inputs and technical education appear to fall into the ranges obtained earlier by the Hayami-Ruttan study. Thus, we will not repeat the economic interpretations for these coefficients. Instead, as an empirical note, we mention that an alternative measure for technical education, defined to be the number of scientists

Table 1. Estimation of the Agricultural Production Function, Separate and Pooled Samples

	(1)	(2)	(3)	(4)	(5)	(6)		(7)	(8)	(9)	(10)	(11)	(12)
Years	1975	1970	1970	55–60–65–70–75	55–60–65–70–75	55–60–65–70–75		1975	1970	55–60–65–70–75	55–60–65–70–75	55–60–65–70–75	55–60–65–70–75
Size of Sample[a]	35	40	40	183	183	183		35	40	183	183	183	183
Dependent Variable	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*		*Y/A*	*Y/A*	*Y/A*	*Y/A*	*Y/A*	*Y/A*
Constant Term	1.874	1.806	1.152	2.093	2.761	1.995		2.041	1.118	2.534	2.619	1.976	1.907
N (labor)	.366	.351	.377	.376	.362	.385	*N/A*	.356	.381	.370	.371	.387	.393
	(5.42)	(3.84)	(4.27)	(12.43)	(11.08)	(12.79)		(5.65)	(4.64)	(11.86)	(11.99)	(13.14)	(13.50)
A (land)	−.030	−.003	.019	.010	.013	.018							
	(−.52)	(−.04)	(.28)	(.35)	(.47)	(.64)							
L (livestock)	.355	.323	.331	.340	.326	.334	*L/A*	.355	.328	.331	.325	.337	.332
	(3.85)	(3.04)	(3.24)	(8.39)	(8.01)	(8.33)		(3.91)	(3.32)	(8.07)	(8.00)	(8.32)	(8.29)
F (fertilizer)	.016	.178	.134	.098	.127	.099	*F/A*	.012	.135	.127	.132	.110	.108
	(.17)	(1.51)	(1.14)	(2.98)	(3.88)	(3.04)		(.14)	(1.17)	(3.91)	(4.06)	(3.44)	(3.41)
M (machinery)	.312	.153	.133	.148	.155	.143	*M/A*	.309	.135	.160	.157	.153	.146
	(3.78)	(1.95)	(1.72)	(5.65)	(6.02)	(5.47)		(3.81)	(1.82)	(6.18)	(6.09)	(5.86)	(5.64)
*GE*1 (general education 1)		.090			−.101					−.091	−.092		
		(.276)			(−.87)					(−.79)	(−.80)		
*GE*2 (general education 2)	−.072		.278	.066		.101		−.077	.275			.047	.089
	(−.35)		(1.34)	(1.03)		(1.57)		(−.39)	(1.35)			(.75)	(1.41)
TE (technical education)	.223	.169	.148	.154	.185	.167		.219	.150	.169	.187	.159	.172
	(3.90)	(2.17)	(1.91)	(5.66)	(7.08)	(6.06)		(3.93)	(2.01)	(6.72)	(7.19)	(5.90)	(6.30)
*D*60					−.032	−.046					−.034		−.047
					(−.47)	(−.67)					(−.49)		(−.68)
*D*65					−.088	−.114					−.095		−.120
					(−1.25)	(−1.60)					(−1.37)		(−1.69)
*D*70					−.146	−.169					−.155		−.177
					(−2.06)	(−2.35)					(−2.21)		(−2.48)
*D*75					−.158	−.179					−.166		−.186
					(−2.08)	(−2.34)					(−2.20)		(−2.44)
Standard Error of Estimation	.280	.336	.327	.291	.289	.288		.276	.322	.292	.289	.292	.288
R-squared	.956	.939	.942	.942	.944	.945		.957	.942	.939	.941	.939	.942

Note: Recall that all regressions are of the log-linear forms as described in the text. Figures in parentheses are *t*-statistics.

[a] The whole sample consists of the following countries: Argentina, Australia, Austria, Belgium (and Luxembourg), Brazil, Canada, Ceylon, Chile, Colombia, Denmark, Finland, France, Federal Republic of Germany, Greece, India, Ireland, Israel, Italy, Japan, Libya, Mauritius, Mexico, Netherlands, New Zealand, Norway, Pakistan, Paraguay, Peru, Philippines, Portugal, South Africa, Spain, Surinam, Sweden, Switzerland, Syria, Taiwan, Turkey, United Arab Republic, United Kingdom, United States, Venezuela, and Yugoslavia. Data for 1970 and 1975 are available from the author on request.

The following countries are dropped from the complete sample: in 1975: France, India, Mauritius, Paraguay, Philippines, South Africa, Surinam, and Taiwan; in 1970: Mauritius, Paraguay, and Surinam; in 1965: Ceylon, Libya, Mauritius, Paraguay, Surinam, Switzerland, and Yugoslavia; in 1960: Libya, Pakistan, Paraguay, Portgual, Surinam, and Yugoslavia; in 1955: Ceylon, Libya, Mauritius, Paraguay, South Africa, Surinam, Switzerland, and Yugoslavia.

and engineers engaged in research and experimental development of agriculture (per ten thousand male farmers) was used to replace the variable *TE* previously defined in the data section. In the 1970 regressions using this new measure, education coefficients are not significantly different from zero.

The estimation for the 1975 agricultural production function is reported in column 1, table 1. Although the sum of coefficients for all conventional inputs is still very close to unity, it is important to observe that the coefficient for fertilizer has declined to a level which is statistically zero while that for machinery has increased considerably from .133 to .312. One also notes that the coefficient for general education is no longer statistically significant, while that for technical education has been raised to a higher level. Obviously, one would be interested to know whether or not the changes in the regression coefficients for various independent variables mentioned in the preceding discussion are of any statistical significance.

Because the production function is nearly linearly homogeneous, it can be easily shown that the coefficients appearing in columns 1, 2, and 3 are obtainable by running appropriate regressions on the basis of per worker levels. The dependent variable would be per worker output, Y/N; and the explanatory variables would be (A/N), (L/N), (F/N), (M/N), GE, and TE. Similarly, one can obtain almost identical estimates for the coefficients α_i's by working with the variables defined in terms of per area unit levels. We have chosen the latter approach because we believe that it lends itself to some interesting interpretations regarding the process of agricultural development.

Columns 7 and 8 report the empirical results of the estimation of the production function on the per-area unit basis. As can be readily verified, the

coefficients appearing in 7 and 8 are similar to those in 1 and 3. They are exactly identical if $\alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 + \alpha_6 = 1$.

The remaining equations in table 1 are designed mainly for the purpose of the covariance analysis. Columns 9 and 11 show the estimation of the pooled sample which consists of the data for the whole period of 1955–60–65–70–75. Note that columns 4, 9, and 11 are estimated with the constraint that all slope coefficients as well as the intercept are unchanged over the whole period under consideration. On the other hand, the estimation reported in columns 5, 6, 10, and 12 are obtained by imposing the constraint of slope homogeneity while allowing the intercept to vary freely. The dummies for 1960, 1965, 1970, and 1975 thus are included in the set of the independent variables in these equations. Interestingly, the coefficients corresponding to the dummy variables *D*65, *D*70, and *D*75 are all statistically smaller than zero. The immediate implication of this result concerning technological progress in agriculture seems to be that the agricultural production function has shifted downward over time. However, in an attempt to interpret this particular finding, one should note that while the coefficients of the time dummies for 1965, 1970, and 1975 are consistently negative, they are estimated with the assumption of homogeneity in the slope coefficients, an assumption which cannot be justified a priori. Thus, in order to examine the possible shift in the intercept of the production function, one would need a complete analysis of covariance to which we now turn.

The Stability of the Agricultural Production Function

The test for stability of the agricultural production function over the whole period of 1955–60–65–70–75 is based on the analysis of covariance, results of which are summarized in table 2A. The first part of the table reports the test, whether there is any difference in the intercepts of the five groups of production functions (each group corresponds to each year in the whole period). The second part is the test for the homogeneity of the slope coefficients of those groups. S_4 in the table is obtained by fitting a separate regression to the data for each group of production functions and then summing the residual sum of squares over all groups. Finally, the third part of the analysis of covariance is derived to test the homogeneity of the overall relationship (intercepts and slopes) over all groups of production functions.

The low values of the *F*-ratios (F_1, F_2, and F_3) indicate that the agricultural production function as a whole is still stable over time. Thus, one would not reject the null hypothesis that the intercepts of

Table 2. Empirical Results of the Analysis of Covariance, 1955–60–65–70–75

A. Specification in Log-Linear Form: $Y_a = f(N_a, L_a, F_a, M_a, GE2, TE)$

Source	Sum of Squares	Degrees of Freedom	Mean Squares	*F*-Ratios
X (pooled sample)	$S = 15.0058$	176		
	$S_2 = 14.2490$	172	.08284	
X and *D*	Differential Intercepts:			$F_1 = 2.28$
(dummy adjustment)	$S_1 = .7568$	4	.18920	
	$S_4 = 11.98944$	148	.08101	
	Differential Slope Vectors:			$F_2 = 1.16$
	$S_3 = 2.25956$	24	.09415	
Overall	$S_5 = 3.01636$	28	.10773	$F_3 = 1.33$

B. An Equation of the Unrestricted Form[a]

$$\begin{aligned}
Y_a = {} & \underset{(4.05)}{1.68} + \underset{(.18)}{.12}(D60) - \underset{(-.54)}{.45}(D65) - \underset{(-.66)}{.56}(D70) + \underset{(.40)}{.36}(D75) + \underset{(5.82)}{.42}N_a + \underset{(.07)}{.01}(N_a \cdot D60) - \underset{(-.23)}{.02}(N_a \cdot D65) \\
& - \underset{(-.41)}{.04}(N_a \cdot D70) - \underset{(-.68)}{.07}(N_a \cdot D75) + \underset{(2.60)}{.28}L_a - \underset{(-.36)}{.05}(L_a \cdot D60) + \underset{(.13)}{.02}(L_a \cdot D65) + \underset{(.38)}{.05}(L_a \cdot D70) \\
& + \underset{(.55)}{.08}(L_a \cdot D75) + \underset{(1.66)}{.11}F_a + \underset{(.37)}{.03}(F_a \cdot D60) + \underset{(.13)}{.01}(F_a \cdot D65) + \underset{(.22)}{.03}(F_a \cdot D70) - \underset{(-.84)}{.10}(F_a \cdot D75) + \underset{(1.08)}{.07}M_a \\
& + \underset{(.42)}{.04}(M_a \cdot D60) + \underset{(.56)}{.05}(M_a \cdot D65) + \underset{(.74)}{.07}(M_a \cdot D70) + \underset{(2.30)}{.24}(M_a \cdot D75) + \underset{(.87)}{.10}GE2 + \underset{(.21)}{.04}(GE2 \cdot D60) \\
& + \underset{(.73)}{.16}(GE2 \cdot D65) + \underset{(.80)}{.17}(GE2 \cdot D70) - \underset{(-.76)}{.18}(GE2 \cdot D75) + \underset{(2.48)}{.19}TE - \underset{(-.55)}{.05}(TE \cdot D60) - \underset{(-.79)}{.08}(TE \cdot D65) \\
& - \underset{(-.40)}{.04}(TE \cdot D70) + \underset{(.31)}{.03}(TE \cdot D75)
\end{aligned}$$

Sample size: 183; S.E. = .284; *R*-squared = .951.

Note: For convenience, the following notation is used: $Y_a = Y/A$; $N_a = N/A$; etc. . . .

[a] This equation is of the log-linear form; *t*-statistics are reported in parentheses.

the separate groups of production functions are not different from each other. Neither would one be able to reject the null hypothesis that the vectors of slope coefficients as a whole are the same among the groups.

However, one should be careful in interpreting these results. While the F_1-ratio is calculated to test the null hypothesis that the intercepts of different equations are all equal, it fails to help us determine whether or not one intercept is statistically different from another. Similarly, the low value of F_2 in table 2A would not eliminate the possibility that some of the coefficients for the production function may have shifted over time.

Results for a regression in which all the intercepts and slope coefficients are allowed to vary are reported in the equation in table 2B. The notation makes it clear that the estimation was obtained on the basis of per area unit levels. A number of interesting observations can be made about this equation. In comparison to the 1955 intercept, the intercepts for later periods appear to be fluctuating around it but do not seem to show any sign of systematic divergence. This result contradicts those reported in columns 10 and 12 of table 1, where all the time dummies for 1965, 1970, and 1975 are statistically smaller than zero. Recall that we have warned against using columns 10 and 12 for an economic interpretation concerning technological progress in agriculture.

Another important point in the equation in table 2B is the significant difference between the machinery-land ratio coefficient in the year 1975 compared to 1955. One should note that the shift in the machinery coefficient has been positive throughout the period, with the highest level attained in 1975. Finally, from the viewpoint of the history of the agricultural development process, it would be interesting to observe the consistent movement of the coefficients associated with the farmer-land ratio variable. Although all of these coefficients are not different from the 1955 coefficient in the statistical sense, there is little doubt about their uniformly negative trend over the period under examination. This particular result seems to be quite consistent with the well-known proposition that the agricultural development process would eventually reduce the number of active farmers per unit of land, and hence the contribution of farm labor in agricultural producing activities. Thus, it does not seem to be a coincidence to observe the opposite directions in which the machinery-land and the farmer-land coefficients have changed.

Concluding Remarks

Our estimation of the production function for both 1970 and 1975 suggests that constant returns to scale still prevailed in the agricultural production pattern. The use of the variable *GE*1, which serves as a proxy for general education, does not seem to indicate a reasonable contribution of general knowledge to the process of agricultural production. On the other hand, the variable *GE*2 shows the positive role of general education in increasing agricultural productivity. Since *GE*2 is defined to be the enrollment ratio for the secondary levels only, this finding may have the policy implication that education at the high school and college levels must be expanded.

The impact of technical knowledge in agricultural sciences on agricultural production requires an additional comment. The coefficients for *TE*, defined to be the number of graduates from agricultural colleges per 10,000 male farmers, are significantly greater than zero throughout. This indicates a positive contribution of this form of human capital in producing agricultural output. On the other hand, the regressions with an alternative measure for technical education, defined to be the number of scientists and engineers engaged in research and experimental development in agriculture, gave insignificant coefficients for technical knowledge. This difference may have something to do with the question of whether basic research or adaptive research is more relevant in the context of agricultural development. This result of our study seems to suggest that the latter type is more relevant since to a large extent, this type may be represented by the variable *TE* in the production function.

The analysis of variance does not completely conform to our expectation regarding the likely instability of the production function over time which was, we thought, due to the emergence of the Green Revolution as well as to the new developments of agricultural science in the second half of the sixties. We tend to speculate here that, while new developments and technology may have altered the pattern of the agricultural production function, their real effect was implicitly realized through the behavior of the conventional and nonconventional inputs as specified in the production function. More specifically, we are able to detect an upward shift over time in the coefficients associated with the farm machinery-land ratio variable, together with a much less clearly downward shift in those corresponding to the farmer-land ratio variable. It is suggested that the effect of farm mechanization in the process of agricultural development may well have been accounted for on the basis of our study.

[*Received October 1978; revision accepted March 1979.*]

References

Chow, Gregory C. "Test of Equality Between Sets of Coefficients in Two Linear Regressions." *Econometrica* 28(1960):591–605.

Fisher, Franklin M. "Test of Equality between Sets of Coefficients in Two Linear Regressions: An Expository Note." *Econometrica* 38(1970):361–66.

Griliches, Zvi. "Research Expenditures, Education, and the Aggregate Agricultural Production Function." *Amer. Econ. Rev.* 54(1964):961–74.

Hayami, Y., and V. W. Ruttan. "Agricultural Productivity Differences among Countries." *Amer. Econ. Rev.* 60(1970):895–911.

———. *Agricultural Development: An International Perspective.* Baltimore, Md.: Johns Hopkins University Press, 1971.

International Labor Office (ILO). *Yearbook of Labor Statistics,* various issues.

Johnston, J. *Econometric Methods,* 2nd ed. New York: McGraw-Hill Book Co., 1972.

Krueger, Anne O. "Factor Endowments and *Per Capita* Income Differences among Countries." *Econ. J.* 78(1968):641–59.

Nelson, Richard R. "A 'Diffusion Model' of International Productivity Differences in Manufacturing Industry." *Amer. Econ. Rev.* 58(1968):1219–48.

United Nations (UN). *Statistical Yearbook,* various issues.

———. Educational, Scientific, and Cultural Organization (UNESCO). *Statistical Yearbook,* various issues.

———. Food and Agriculture Organization (FAO). *Production Yearbook,* various issues.

The Economics of Adopting Solar Energy Systems for Crop Irrigation: Comment

J. Walter Milon

In a recent article, Katzman and Matlin (KM) present a parametric analysis of the viability of solar photovoltaic systems for meeting crop irrigation energy demands. KM can be commended for developing an analytical model flexible enough to evaluate the considerable uncertainty surrounding solar technology and for pointing out potential applications. However, their analysis obfuscates the distinction between social and private benefits. The proper definition of these benefits has important implications for determining the viability of photovoltaic systems and public policy toward alternative energy systems.

KM define the energy-related social benefits as the difference between farm energy demands for conventional fuels with and without solar photovoltaic power generation—equation (5). Except for an additional tax adjustment, the same definition is used in calculating the private benefits—equation (7). Assuming, as KM do in equation (4), that the photovoltaic performance is reliable enough to eliminate the need for an auxiliary system using conventional fuels (diesel, gas, etc.), the social and private benefits are equal. However, if the photovoltaic system interfaces with an electric power grid using a traditional tariff schedule based on the average cost of service, the benefits are not equivalent. Williamson and Panzar have proved that the welfare-maximizing price for electricity is equal to the electric system's marginal cost. Since electric utility generating plants are used in order of their running efficiency, the system-wide marginal cost curve is upward sloping (Wenders). As a result, the timing and magnitude of changes in the utility's load curve will influence significantly the social benefits from interfacing photovoltaic systems.

Letting *CFX* be the social and private benefits defined by KM and *CFY* the welfare-maximizing price, we can identify some important policy considerations. In areas where farm electricity demand is coincident with system peak demand, photovoltaic generation will substitute for high variable cost (low fixed cost) peaking equipment. As a result, *CFY* will be greater than *CFX*, and social viability may precede commercial viability. An integrated design of photovoltaic systems, storage capability, and regional load-leveling centers could increase substantially the delivery efficiency of the power system. In this situation, public policy should encourage photovoltaic or other alternative energy systems through tax incentives or subsidies.

On the other hand, if farm electricity demand occurs during system off-peak periods when utility energy is least expensive, *CFY* will be less than *CFX* and private viability will precede social viability by a longer period than that suggested by KM (table 1). Under a traditional tariff schedule, a redistribution of income from nonsolar to solar customers would occur as the nonsolar customers compensate for the decline in utility revenue (assuming a constant return to equity regulatory constraint). As suggested by Asbury and Mueller, proper public policy in these regions would encourage power storage systems using the inexpensive off-peak electricity instead of increasing capital investment through acquisition of photovoltaic systems.

The rate design standards outlined in the Public Utility Regulatory Policies Act of 1978 would, if implemented, mitigate the distinction between social and private benefits discussed here. However, the voluntary nature of these guidelines implies that compliance will be slow. The studies cited by Kelly indicate that there are significant regional differences between the performance characteristics of photovoltaic systems. The framework suggested by KM for determining the optimum investment in photovoltaic systems cannot be considered correct unless the proper distinction between social and private benefits is realized.

[*Received December 1978; revision accepted January 1979.*]

J. Walter Milon is an assistant professor, Food and Resource Economics Department, University of Florida.

References

Asbury, Joseph G., and Ronald O. Mueller. "Solar Energy and Electric Utilities: Should They Be Interfaced?" *Science* 195(1977):445–50.

Katzman, Martin T., and Ronald W. Matlin. "The Economics of Adopting Solar Energy Systems for Crop Irrigation." *Amer. J. Agr. Econ.* 60(1978):648–54.

Kelly, Henry. "Photovoltaic Power Systems: A Tour through the Alternatives." *Science* 199(1978):634–43.

Panzar, John C. "A Neoclassical Approach to Peak Load Pricing." *Bell J. Econ.* 7(1976):521–30.

Wenders, J. T. "Peak-Load Pricing in the Electric Utility Industry." *Bell J. Econ.* 7(1976):232–41.

Williamson, Oliver E. "Peak Load Pricing and Optimal Capacity under Indivisibility Constraint." *Amer. Econ. Rev.* 56(1966):810–27.

The Economics of Adopting Solar Energy Systems for Crop Irrigation: Reply

Martin T. Katzman and Ronald W. Matlin

The purpose of our essay was to provide a flexible methodology for evaluating solar technologies in irrigation, with particular attention to identifying the parameters that have the greatest impact on profitability. To avoid complications such as regional variations in sources of power or current tariff structures, the analysis was perhaps more institution-free than some readers would prefer. The solar photovoltaic-power system was compared to a conventional one with onsite generation, a common condition in Texas, Nebraska, and New Mexico. The irrigation benefits were defined as the asymptotic world price of fuel rather than any prices derived from existing tariffs. These asymptotic fuel costs reflect fairly well the marginal social costs of irrigation. Thus, we take exception to the commentator's statement that our framework for determining the optimum period of investment in photovoltaic systems cannot be considered correct.

We welcome Milon's extension of our analysis to conventional irrigation systems powered by the central grid, the common situation in Arizona and California. As Milon shows, calculating social and private benefits is more complicated than under our conditions of on-site generation.

Without performing the calculations, one cannot say whether variations in pricing schemes, under any load-curve characteristics, have as decisive an impact on the viability of solar photovoltaic systems as, say, variations in fuel escalation rates or the cost curve of the array. Anticipating load-curve characteristics or the implementation of the Public Utility Regulatory Policies Act in the 1980s and 1990s in particular regions seems beyond our modest capacities; however, as we approach these years, the calculations suggested by Milon should be undertaken before adopting solar systems in particular circumstances.

Contrary to Milon's statement in paragraph two, social and private benefits are never equal. Depreciation and allowances, investment tax credits, and income taxes result in lower gross and net private benefits than social benefits.

[*Received January 1979.*]

Martin T. Katzman is a professor of political economy and head of the graduate program in political economy at the University of Texas-Dallas; Ronald W. Matlin is assistant project manager of Solar Photovoltaic Field Tests and Applications Project, Lincoln Laboratory, Massachusetts Institute of Technology.

Oligopoly Pricing in the World Wheat Market: Comment

Thomas Grennes and Paul R. Johnson

Alaouze, Watson, and Sturgess (AWS) have recently revived the argument that the world wheat market is oligopolistic. McCalla described the market as a United States-Canadian duopoly, and the innovation of AWS is to convert the club into a triopoly by adding Australia. We are generally skeptical about the ability of oligopoly models to explain the behavior of world wheat prices, and oligopoly appears especially inappropriate in view of events since 1971. We offer two comments concerning the AWS paper. First, variation in market structure is dominated by other variables in terms of explaining the actual variation in wheat prices. Second, the logic of the triopoly model presented by AWS has several shortcomings.

The World Wheat Market as an Oligopoly

The characterization of the wheat market as oligopolistic is motivated by two undeniable facts: (*a*) the large shares of United States and Canadian firms in export markets, and (*b*) historical attempts of major exporters to collude. McCalla alluded to meetings between the United States and Canada, and AWS refer to meetings between those two countries and Australia as evidence of duopoly and triopoly, respectively. Attempted collusion by wheat exporters is not in dispute, because there has been a continuous and overt effort to implement the various international wheat agreements since the 1930s, and a new agreement was being negotiated in early 1979. However, as empirical studies in industrial organization have shown, the desire by firms or governments to collude is not sufficient to achieve a price in excess of marginal cost. One of the reasons that the Organization of Petroleum Exporting Countries (OPEC) has fascinated economists is that its success in disciplining member states contrasts so sharply with the failure of other commodity agreements; international wheat agreements have been notable for their failure to keep prices within the agreed range (Behrman). Because substantial barriers to wheat trade result in price differences across countries, the notion of a world wheat price is somewhat ambiguous. We interpret the U.S. price as the best index of a world price because it is the largest exporter and the U.S. government has imposed the least trade controls (see Grennes, Johnson, Thursby, 1978a, chap. 7–8). The behavior of wheat prices since 1971 is dramatic evidence of lack of oligopoly discipline (see table 1). AWS refer to a stable oligopoly prior to 1972 (p. 173), but they neglect the fact that real wheat prices (money prices deflated by the consumer price index) stabilized in the three previous years at the lowest level since 1932. AWS offer a curious interpretation of wheat prices after 1972. "Since 1972, the world wheat market has been characterized by high, unstable prices and low carryover stocks, indicating that the market has been operating essentially competitively" (AWS, p. 173). There are two problems with this statement. First, prices have not been high since 1972. They increased sharply in 1973 (doubling in one year); but they also declined quickly, so that by May 1977, prices had returned to Great Depression levels ($2.33 in current dollars or $1.30 in 1967 dollars). By the end of 1978, prices had increased slightly to the neighborhood of $1.70; but real wheat prices in 1977 and summer 1978 averaged less than 90% of the previous forty-four years. Substantial inventory accumulation has prevented a larger price decline. The second problem with the above statement is that the sharp price increase in 1973 is hardly convincing evidence that a stable oligopoly had deteriorated into a competitive price war.

Oligopoly is a market structure lying somewhere between competition and monopoly. Presumably those observers who stress lack of competition describe the wheat market as oligopolistic rather than monopolistic because of the number of producers and the periodic occurrence of price wars.[1] However, the more frequently price wars occur, the closer is price to marginal cost, and the more closely the wheat market approaches competitive conditions. Our interpretation of the data is that price cutting has dominated monopoly pricing and that oligopoly is not a useful description of the wheat market. An example of this price behavior is the failure to enforce the minimum price provisions of the International Wheat Agreement. The trend of real wheat prices has been downward since 1947,

Thomas Grennes and Paul R. Johnson are associate professor and professor, respectively, in the Department of Economics and Business, North Carolina State University.

Paper 5881 of the Journal Series of the North Carolina Agricultural Experiment Station, Raleigh.

[1] "We interpret the price wars as indicating an unstable duopoly situation because of the actual or potential erosion of one or both of the market shares of the duopolists by other exporters" (AWS, p. 175). If the duopoly is frequently unstable, there is not much of an excess of price over marginal cost for the duopoly model to explain.

Table 1. U.S. Wheat Prices for Selected Years, 1913–78

Crop year	Current Dollars per Bushel	1967 Dollars per Bushel	Crop Year	Current Dollars per Bushel	1967 Dollars per Bushel
1913	.88	2.96	1957	2.20	2.61
1915	1.29	4.24	1958	2.03	2.34
1917	2.30	5.99	1959	1.98	2.27
1919	2.42	4.67	1960	1.99	2.24
1921	1.33	2.48	1961	2.01	2.24
1923	1.11	2.17	1963	2.18	2.38
1926	1.50	2.83	1964	1.88	2.02
1930	.90	1.80	1965	1.56	1.65
1932	.49	1.20	1966	1.79	1.84
1935	1.04	2.53	1967	1.67	1.67
1939	.76	1.83	1968	1.47	1.41
1944	1.60	3.04	1969	1.39	1.27
1947	2.60	3.89	1970	1.48	1.27
1949	2.15	3.01	1971	1.60	1.32
1950	2.23	3.09	1972	2.26	1.80
1951	2.40	3.08	1973	4.83	3.63
1952	2.39	3.01	1974	4.29	2.90
1953	2.24	2.80	1975	4.08	2.53
1954	2.31	2.87	1976	2.88	1.69
1955	2.26	2.82	1977	2.72	1.50
1956	2.22	2.73	1978[a]	3.44	1.72

Note: Prices refer to No. 2 hard red winter wheat at Kansas City.
Sources: *Historical Statistics of the United States, Agricultural Statistics* and *Wheat Situation.*
[a] 8 Dec. 1978.

and the sharp fluctuation of prices in the 1970s cannot plausibly be explained by changes in market structure.

One can describe the world wheat market as approximately competitive without implying that it is efficient in the sense of Pareto. It is well known that the wheat market is heavily regulated by governments at all levels of activity, and many of these regulations result in misallocation of resources. Nevertheless, many regulations, such as tariffs, price supports, and production quotas, can be represented by competitive models (Grennes, Johnson, Thursby 1978a, Chap. 4; Schmitz and Bawden) while achieving satisfactory empirical results. Thus, the existence of policy-induced distortions in the wheat market does not preclude positive economic analysis based on competitive models.

We find that variation in world wheat prices is better explained by government policy than by changes in market structure, but the two explanations are not unrelated (Johnson, Grennes, Thursby). When government policy calls for export restriction, the resulting increase in the foreign price is consistent with oligopoly behavior by exporting countries. However, when policy calls for export promotion, the resulting price decline violates oligopoly behavior. Our interpretation of policy is that governments restrict or promote wheat exports depending on their domestic agricultural goals rather than trying to maximize national income from wheat exports which would result from oligopoly pricing. A domestic wheat price above the competitive level has been a traditional U.S. policy goal, and export promotion has been a technique for achieving this goal without resorting to direct payments, larger inventories, or production controls. Export promotion has taken many forms including concessionary sales, export subsidies for commercial sales, subsidized export credit, or increasing export quotas. Wheat boards may accomplish this more directly by quietly increasing the amount of wheat offered to the export market or raising the price to domestic buyers. The dominance of domestic policy goals in agricultural trade policy has been stressed for decades by D. Gale Johnson, and evidence from the 1970s continues to support that hypothesis. One of the reasons that oil is a more effective cartel than wheat is that OPEC can restrict oil exports without complaints from domestic producers, but the USDA cannot restrict wheat exports without strong resistance from U.S. wheat farmers. (Recall the discussion of the U.S. "grain embargo" during the 1976 presidential election.) Thus the dominance of domestic policy goals erodes the potential oligopoly power of the major exporters. During periods of downward pressure on world wheat prices, U.S. policy has tended to liberalize Public Law 480 shipments, increase export subsidies (recall the USSR's Great Grain Robbery of 1972), and promote market development. (Greater sales to the People's Republic of China is a prominent goal of the U.S. Agricultural Trade Act of 1978.) These and similar policies have resulted in an export volume which has depressed wheat prices below oligopoly levels.

Shortcomings of the AWS Triopoly Model

Because the AWS triopoly model is vaguely specified, it is not easy to interpret. If loosely interpreted, it cannot be distinguished from competition and if strictly interpreted the model contains logical errors. What distinguishes the AWS contribution from McCalla is the claim that a three-country oligopoly explains more than a two-country oligopoly, but they offer little evidence as to why a quadropoly, for example, would not provide even more explanatory power than a triopoly. In terms of export volume the United States, Canada, and Australia are the largest national exporters, but Western Europe exported more than Australia in crop year 1978–79 (*Wheat Situation*, Nov. 1978), Argentine exports cannot be ignored, and the USSR has been an important exporter until recently. AWS cite a meeting between U.S., Canadian, and Australian officials as evidence of three-country collusion, but there has been continuous contact for years involving a larger group of countries under the au-

spices of the various wheat agreements (a new agreement is currently being negotiated). Their emphasis on the independence of the triopoly leads AWS to refer to the "exportable surplus" of fringe exporters as if this were a fixed amount independent of the triopoly price. Theory and evidence indicate that both the excess supply of other exporters and import demand are responsive to the triopoly price, and the effect is to increase the elasticity of demand facing the three. A related point concerns the optimum triopoly price. AWS state (p. 184) that the triopoly price is greater than the duopoly price, which suggests that adding countries to an oligopoly raises the optimum price. If this is generalizable, then the competitive price (n-opoly?) should exceed the monopoly price, which is an implication contrary to received doctrine. Thus, AWS have not established the superiority of triopoly over either smaller or larger oligopolies.

A second shortcoming concerns the object of the wheat oligopoly. If members were private firms, profits would be the natural object, but government marketing boards and the USDA are not profit-making institutions, and they frequently pursue policies which lower the national income in order to transfer income to particular domestic groups. As mentioned above, when domestic policy goals conflict with oligopoly discipline, the latter tends to be sacrificed. AWS are vague about oligopoly objectives, mentioning maximum revenue (p. 179), stable market shares (p. 175), and maximum exports (p. 174). Costs are ignored as if they were irrelevant or equal for all triopolists, but how can one explain the observed differences in market shares unless costs are different?

Even if the triopolists agreed on an objective, how would they enforce the arrangement? Export or production controls would be required for members, and nonmembers must be discouraged from growing more wheat. Since the industry is characterized by many firms with easy entry, enforcement is a problem.[2] AWS concede that price cutting is difficult to detect because of the many grades of wheat (p. 176), although at another point they assert that wheat is a homogeneous good (p. 174). In either case the triopoly has a problem because heterogeneous wheat causes an enforcement problem and homogeneous wheat increases the elasticity of demand facing the three.

Inventories and stable market shares are said to play an important role in the triopoly model (pp. 181–82), but it is difficult to determine from the discussion of AWS how observations on these variables permit one to distinguish triopoly from competition. For example, the class of constant market share trade models (Leamer and Stern) assumes competitive markets, and those models have the property that market shares remain constant unless relative prices change. What distinguishes competitive from noncompetitive behavior is price relative to marginal cost, and that relationship does not restrict market shares. Stable market shares are consistent with a small total market where price exceeds marginal cost or a larger competitive market where price equals marginal cost.

AWS claim that willingness and ability to hold inventories is a measure of monopoly power (p. 181). The literature on inventories is based on uncertainty about future prices, and most of the work dealing with how hedgers and speculators react to uncertainty assumes competitive markets (see, e.g., Telser on the demand for storage). AWS argue that the depletion of wheat stocks in 1971 caused the triopolists to lose their market power (p. 182). Curiously this erosion of market power resulted in real wheat prices rising to the highest level since 1947. Neither is there much evidence of renewed potency of the oligopoly as stocks have accumulated recently. AWS expect the variability of wheat prices to depend on the level of triopoly inventories (p. 184), but the same relationship holds for competitive conditions. Thus, inventory behavior provides no discriminatory power with respect to market structure.

Despite some descriptive appeal, the class of oligopoly models fails to explain the pattern of world wheat prices, especially in the 1970s. An alternative explanation, in addition to the vicissitudes of nature, is foreign trade policy as determined by domestic agricultural goals. In terms of future research, we would expect a larger payoff to modeling the interdependence of national trade policies than to formulating more complex oligopoly models.

[*Received September 1978; revision accepted April 1979.*]

[2] The discussion of the structure of international wheat trade frequently takes the nation as the appropriate trading unit. This may be proper for countries with state trade monopolies but in the United States wheat is traded by private firms. For a study of the industrial structure of private grain trade, see Richard E. Caves.

References

Alaouze, Chris M., A. S. Watson, and N. H. Sturgess. "Oligopoly in the World Wheat Market." *Amer. J. Agr. Econ.* 60(1978):173–85.

Behrman, Jere. *Development, the International Economic Order, and Commodity Agreements.* Reading, Mass.: Addison-Wesley Publishing Co., 1978.

Caves, Richard E. "Organization, Scale, and Performance in the Grain Trading Industry." Harvard University Inst. of Econ. Res. Disc. Pap. No. 546, Apr. 1977.

Grennes, Thomas, Paul R. Johnson, and Marie Thursby. *The Economics of World Grain Trade.* New York: Praeger Publishers, 1978a.

———. "Insulating Trade Policies, Inventories, and Domestic Wheat Price Stability." *Amer. J. Agr. Econ.* 60(1978b):132–34.

Johnson, Paul R., Thomas Grennes, and Marie Thursby.

"Devaluation, Foreign Trade Controls, and Domestic Wheat Prices." *Amer. J. Agr. Econ.* 59(1977):619–27.

Johnson, D. Gale. *Trade and Agriculture: A Study of Inconsistent Policies.* New York: John Wiley & Sons, 1950.

Leamer, Edward E., and Robert Stern. *Quantitative International Economics.* Boston: Allyn & Bacon, 1970.

McCalla, Alex. "A Duopoly Model of World Wheat Pricing." *J. Farm Econ.* 48(1966):711–27.

Schmitz, Andrew, and D. Lee Bawden. *The World Wheat Economy: An Empirical Analysis.* Berkeley: Giannini Foundation Monograph No. 32, University of California, Berkeley, 1973.

Telser, Lester. "Futures Trading and the Storage of Cotton and Wheat." *J. Polit. Econ.* 66(1958):233–55.

U.S. Department of Agriculture. *Agricultural Statistics.* 1977.

———. *Wheat Situation.* Various issues.

U.S. Department of Commerce. *Historical Statistics of the United States.* Washington, D.C., 1975.

Oligopoly Pricing in the World Wheat Market: Reply

Chris M. Alaouze, A. S. Watson, and N. H. Sturgess

Grennes and Johnson (GJ) have criticized our recent paper "Oligopoly Pricing in the World Wheat Market" on several grounds, some of which suggest that they have misunderstood our triopoly model. In this reply we attempt to answer their major points of disagreement and at the same time reemphasize the essential points of our original paper.

In the first instance, we reject comparisons of our paper with results from "empirical studies in industrial organization" or recent experience with oil prices. Our paper was concerned with the year-by-year selling and storage decisions of statutory authorities in Canada and Australia and the analogous problem confronted by the United States—although its essential similarity is masked by the different price support and regulatory mechanisms that have been used. In this sense, to seek "to achieve a price in excess of marginal cost" has nothing to do with the problem at hand. Our analysis is in the spirit of the stock period, as defined by Schultz, when "once the crop is harvested, one is necessarily restricted to the particular stock until the next crop becomes available."

Nowhere in the Alaouze, Watson, and Sturgess (AWS) article is it stated that the triopoly is always operating. In fact, the point of our exercise was to demonstrate how different market structures could eventuate in response to different supply and demand situations over time. Necessary conditions for the formation of the triopoly are outlined (p. 183), and these clearly are not satisfied by the demand and supply conditions of the 1972/73 season. Lack of "oligopoly discipline" plays no part in the breakdown of triopoly pricing. Supply and demand do.

The real wheat prices (table 1) by which GJ judge price levels are not relevant to the analysis because the AWS paper sets out to explain nominal prices. It also should be noted that the nominal price series in table 1 of the GJ paper does support our statement that prices have been high and unstable since 1971 (as compared with preceding years) and that at the time of publication of the AWS paper (May 1978) prices were declining. We must confess, however, that we have an antipodean perception of the course of wheat prices over the 1970s because we think (most of the time) in Australian currency terms. Even if they were relevant, an Australian series of real wheat prices would look very different from those in table 1 of GJ.

GJ argue that oligopoly is not a useful description of the wheat market. The major evidence cited for this conclusion is that the minimum price provisions of the International Wheat Agreement were not enforced. In response, we would like to point out that we provided evidence that the triopoly was operating in the 1968/69 season at prices below the minimum price provisions of the International Grains Arrangement then in operation. Incidentally, the minimum price provisions of the International Grains Arrangement were set (on average) 19¢ per bushel higher than those of the preceding International Wheat Agreement (AWS pp. 176–77). There is no requirement for realism on the part of the participants when drafting international commodity arrangements. We note, however, that subsequent international grain arrangements have not specified minimum prices.

We agree that "the wheat market is heavily regulated by governments at all levels of activity." GJ prefer to represent the pricing outcomes that occur in the wake of these extensive regulations as "approximately competitive." In the world wheat market as we understand it, there are few sellers, there are frequently large publicly held stocks (or private stocks induced by public pricing policies), and there are government-to-government sales. We cannot regard this as "approximately competitive." However, we do not view the intermittent situations which we believe can be interpreted with oligopolistic models in the way that GJ have attributed to us. We do not regard "variation in wheat prices" as being explained by "changes in market structure." Rather, changes in behavior and in market structure are explained by changes in supply and demand in the world wheat market.

GJ have described policies of export promotion which, they argue, depress prices and contradict oligopoly behavior. Such policies include concessionary sales (dumping?), export subsidies for commercial sales, subsidized export credit, and increasing export quotas. We believe these are practices usually associated with less-than-perfect competition. Regrettably, we cannot comment on references to disputes over U.S. grain policies during U.S. presidential elections; nor can we see the relevance to anything in our paper of the passing reference by GJ to the "USSR's Great Grain Robbery of

---

Chris M. Alaouze is a teaching assistant in the Department of Economics, University of Wisconsin, formerly at the University of Melbourne. A. S. Watson and N. H. Sturgess are senior lecturers in agricultural economics at the University of Melbourne.

1972" except that we would point out that we are fully aware that the ambitions of those who seek to regulate markets are not always fulfilled.

In their discussion of the shortcomings of our model, GJ suggest that it is derived from McCalla. In fact, we have attempted to generalize Taplin's model. The extension of our model to a fourth country, such as Argentina, would be straightforward. In any case, we see a clear difference between the situation of the wheat exporting countries and the EEC and USSR. The EEC trades most of its wheat among member countries, which we would not regard as "exports" and occasionally sells (dumps) wheat on the world market. USSR trade is highly volatile while Argentina's trade is small relative to the three major exporters.

GJ confused the discussion on p. 184 of our paper concerning optimal triopoly and oligopoly prices. In our model, the more countries that combine to set prices the closer the situation is to monopoly rather than to competition as suggested by GJ. If countries were "added" to the oligopoly, the residual demand curve facing this new oligopoly would shift outwards. If all countries were added, the residual demand curve facing them would be the industry demand curve. This n-opoly would act as a pure monopolist along the industry demand curve.

We cannot defend ourselves against the charge that we are "vague about oligopoly objectives" because we believe that the weightings given to revenue, market shares, and exports as objectives by individual countries will change over time. Whatever the mix of objectives favored by the major wheat exporting countries, we fail to see how "costs" are relevant, in whatever sense is intended by GJ.

GJ have questioned the enforcement of a triopoly arrangement. We would not suggest that a neat and tidy arrangement could exist or has existed in the past. We note, however, that at various times the principal wheat exporting countries have used production controls and maintained substantial stocks. We dispute that "the industry is characterized by many firms with easy entry" for reasons clear from the above. We could note that our paper arose from the attempt to explain high Australian stocks from 1969 to 1971. Do GJ believe that the policies of stock holding and production quotas pursued by Australia were the sorts of policies that would have been pursued in an "approximately competitive" world wheat market? With respect to "easy entry," if another country starts to become important (as Australia started to be in the late 1960s) then they could be absorbed into the oligopoly. When high wheat stocks exist, threats of price cutting would encourage expanding producers of wheat to join the cartel.

GJ argue that it is difficult to determine from our discussion how observations on inventories and market shares permit our readers to distinguish triopoly from competition. As it happens, our paper on oligopoly in the world wheat market developed from another study (Alaouze, Sturgess, Watson 1978) in which we studied the inventory problem confronting the Australian Wheat Board. Two models were available for the demand side of the model. First, the duopoly models of McCalla and Taplin which led to the conclusion that the demand for Australian wheat was infinitely elastic at the world price. Second, the competitive model in which the elasticity of demand for Australian wheat would be computed using the market share formula—a calculation similar to the application of this formula outlined in AWS (p. 181). Both approaches would have concluded that the demand for Australian wheat exports was elastic. However, the following facts: the 7.2 million tonne Australian carryover in the 1968/69 and 1969/70 seasons, the accompanying silo construction program, and the threat of a price war in 1968/69 (AWS pp. 176–177) were inconsistent with an elastic demand for Australian wheat exports in those seasons, given that the Australian Wheat Board had previously pursued a policy of selling its exportable surplus. Therefore, we were led to reject the two duopoly models and the competitive model as an adequate description of pricing in the world wheat markets after the 1968/69 season.

Furthermore, GJ's criticism of our interpretation of inventories and market shares is based on published works which address issues unrelated to that under discussion. First, their reference to the Leamer-Stern (two-country) model is misleading. The Leamer-Stern market-share model implies a highly stylized supply function in which the supply of a particular good is completely determined by the price of that good alone. Therefore, constant crises imply constant market shares. The market-share equation on which their model is based implies the even stronger assumption that market shares are constant when the selling price ratio is constant. This paradigm clearly is not applicable to commodities such as grain which are typically produced by multiproduct firms using many factors of production. The Leamer-Stern model also ignores yield-induced variations in production. Second, the statement that "most of the work dealing with how hedgers and speculators react to uncertainty assume competitive markets" is irrelevant to the question of the actual structure of the world wheat market.

In conclusion, GJ state that "the class of oligopoly model fails to explain the pattern of world wheat prices, especially in the 1970s." The analysis of our paper included the use of the model to show how the triopoly can break down when faced with an episodic increase in demand (as occurred in the 1972/73 season) (AWS pp. 182–84). Therefore, we are being criticized for a claim we would not make for our work.

[*Received December 1978.*]

References

Alaouze, Chris M., A. S. Watson, and N. H. Sturgess. "Oligopoly Pricing in the World Wheat Market." *Amer. J. Agr. Econ.* 60(1978):173–85.

Alaouze, Chris M., N. H. Sturgess, and A. S. Watson. "Australian Wheat Storage: A Dynamic Programming Approach." *Aust. J. Agr. Econ.* 22(1978):158–74.

Leamer, Edward E., and Robert Stern. *Quantitative International Economics.* Boston: Allyn & Bacon, 1970.

Schultz, Theodore W. *The Economic Organization of Agriculture*, p. 176. New York: McGraw-Hill Book Co., 1953.

Books Reviewed

Bell, Frederick W. *Food from the Sea: The Economics & Politics of Ocean Fisheries*. Westview Special Studies in Natural Resources and Energy Management. Boulder, Colo.: Westview Press, 1978, xxvi + 380 pp., $25.00, $12.00 paper.

Since the U.S. Congress voted to extend the country's exclusive fishing zone to 200 miles in 1976, interest in the fishing industry has grown considerably. Investors and fishermen are eager to cash in on the expected bonanza when fish stocks return to abundance after concentrated fishing by foreign fleets stops. The management of these fisheries resources present interesting problems to both theoretical and applied economists. With the additional interest in fisheries stimulated by the current Law of the Sea negotiations, the time is right for a comprehensive text on the economies and politics of ocean fisheries.

Frederick Bell, active in fisheries economics research for many years, provides in this book a useful presentation of the basic economic analysis of fisheries and of some of the management strategies used and proposed. As well as explaining supply and demand for fisheries products and basic economic analysis for the firm and the industry, Bell examines the potential contributions of aquaculture and underutilized fishery resources to fish supplies. He includes a chapter on recreational fishing which covers standard economic approaches to the valuation of recreational fishing. The problems of applying effective fisheries management and the role of national governments and international commissions in fisheries management are discussed in other chapters. Inclusion of a chapter on the effects of environmental deterioration on fishery resources is unusual but wise; for anadromous species (such as salmon) and for sedentary shellfish (such as oysters), pollution has further depleted stocks which have been severely overfished.

Since the book was written—apparently before 1977—rapid changes have taken place in many U.S. fisheries. Particularly in New England, earnings of fishermen, investment in new boats and restriction of fisheries management have radically altered the economic situation of the fishing industry from that pictured in Bell's book. However, this change provides a foil for the instructor to illustrate how economic incentives alter exploitation patterns. The text's presentation of basic economic analysis in fisheries remains applicable, and Bell's points about the incentives to overexploit a common property resource and about the failings of traditional management techniques are demonstrated anew by current developments in the traditional fisheries.

The book contains some misrepresentations. For example, tuna (a highly migratory species) is explicitly excluded from regulation under the Fisheries Conservation and Management Act. The section on bioeconomic modeling is necessarily limited in its scope; the more interested student should obtain information on more current and complex modeling developments from Lee Anderson or, on a more advanced level, Colin Clark. The author's prose is reasonably clear, though punctuated by curious excursions into levity. These reservations are relatively minor and do not mar the book's basic usefulness.

The book should be useful as an undergraduate text for introductory courses in natural resource economies or fisheries economics. However, some of the economic analysis may be demanding for students with no previous economics, so the instructor should be selective in assigning sections of the book. The comprehensive discussion of applied aspects of fisheries economics provides a review of some basic facts about world fisheries and discusses the economics of various U.S. fisheries in particular; those engaged in fisheries management may find the book a convenient reference for these facts. A few additional tables listing, for example, the various international fisheries commissions, would have greatly improved the book's usefulness as a reference.

This book deserves attention during this time of rapid development of U.S. fisheries management policy, a time when the economic and social aspects of fisheries management are the object of more careful and systematic attention than ever before.

Leah J. Smith
Woods Hole Oceanographic Institution

References

Anderson, Lee G. *The Economics of Fisheries Management*. Baltimore, Md.: Johns Hopkins University Press, 1977.

Clark, Colin. *Mathematical Bioeconomics; The Optimal Management of Renewable Resources*. New York: John Wiley & Sons—Interscience, 1976.

Binswanger, Hans P. *The Economics of Tractors in South Asia—An Analytical Review*. New York: Agricultural Development Council, and Hyderabad, India: International Crop Research Institute for the Semi-Arid Tropics, 1978, 96 pp., price unknown.

The book under review is devoted mainly to the

scope of tractorization in South Asia. The use of tractors in low wage countries has been the center of one of the most virulent and emotional choice-of-techniques debates for the past twenty years. The author has tried to make an analytical review of the scope of tractorization as it is related to agro-climatic, social, labor employment, and economic factors. The benefit of tractors has been discussed from two apparently contradictory views. The substitution view looks at tractors and animals as two power sources which are technically perfect substitutes. The opportunity costs of labor and bullocks have been compared with tractors, also taking into account social and economic aspects. The author also discusses the net contributory view of tractors on production, profit, timeliness, and labor employment aspects, using survey data to aid his discussion. He critically analyzes the benefit-cost relationship of the use of tractors in this part of the world.

After reviewing various empirical studies, the author concludes that tractors are not responsible for the substantial increase in intensity, yields, timeliness, and gross returns on farms in India, Pakistan, and Nepal. Benefit-cost studies also show that the use of tractors does not yield much benefit. Private returns to tractors from agricultural operations are close to zero, or even negative except in situations where area efforts are possible (by renting or buying) or in very semi-arid tracts.

The drudgery of farm work is reduced with the use of tractors, but, in an environment of stagnant or declining wages, although the loss of employment may relieve landless laborers of drudgery, it clearly will increase rather than reduce their overall sufferings. While the data show that tractor farms generally do not use less labor than do bullock farms, this may be due to increased productivity and higher capital use on tractor farms quite aside from the use of tractors per se.

The Economics of Tractors in South Asia is an excellent brief but critical review of numerous papers and reports published by renowned agricultural scientists, engineers, economists, and statisticians of the world at large and of Southeast Asian countries, in particular. The subject matter is presented clearly and the conclusions are argued well. However, the data collected through the survey methods have certain limitations, especially at the adoption stage of modern technology by farmers. The manner in which the author describes the limitations of the data derived from the survey reports which form the main source of reference for the book is much appreciated. It is the final conclusion of the book that tractorization in South Asia may not be of great benefit, taking into account the production, social, and economic aspects at the present stage of agro-socioeconomic conditions.

I wish to add a note from my own observations of the subject. Data obtained at research stations clearly show that tractors as a supplementary source of power will be required if cultivation is to be done on a scientific basis under irrigation. The Indian government is trying hard to increase the irrigated area, thereby cropping intensity certainly will increase. The increased cropping intensity will require more power to complete the job in comparatively less time than in monocropping. For existing farm technology, bullock power is sufficient, and that is one of the reasons that tractors are not profitable. However with the adoption of modern technology and the resultant higher cropping intensity, there will be need of more power. Experiments show that to accomplish farm work in a timely manner it is more economical to supplement power by using tractors rather than bullocks.

R. S. Tripathi
Indian Institute of Technology, Kharagpur

Granger, C. W. J., and Paul Newbold. *Forecasting Economic Time Series*. New York: Academic Press, 1977, xiii + 333 pp., $22.00.

The authors of this book, two distinguished statisticians with wide empirical and theoretical experience, are obviously well qualified to write such a text, and the end result of their collaboration is an excellent book which should prove an invaluable tool for econometricians interested in forecasting economic time series.

The first several chapters of the work cover the mathematical prerequisites for the text including a brief survey of the theory of difference equations, autoregressive processes, moving average processes, and mixed autoregressive integrated moving average processes. A brief, but excellent, survey of the methods of spectral analysis is contained in chapter 2. This chapter, however, appears to be extraneous to the main purposes of the text, because spectral techniques are dealt with only infrequently thereafter. As such, this chapter probably could be skipped without too much loss of continuity. Chapter 3 includes a concise discussion of the theory and practical methods of constructing linear time-series models. The remaining chapters deal with methods for forecasting economic time series and forecast evaluation.

The modeling methodology suggested by Granger and Newbold closely follows that proposed by Box and Jenkins in their various works on time series analysis, forecasting, and control. Especially important is the three-step iterative cycle strategy for constructing autoregressive integrated moving average models. The cycle consists of a model identification step, a model estimation step, and, finally, diagnostic checks on model adequacy. This technique allows the would-be model builder an excellent practical method of determining the adequacy of alternative models used to forecast economic time series.

From the forecasting point of view, Granger and Newbold go beyond Box-Jenkins methods by giving particular attention to the concept of combined

forecasting. As illustrations, they discuss the feasibility of combining forecasts generated by a Box-Jenkins type model with forecasts generated by a purely automatic prediction process, such as exponential smoothing, or by stepwise autoregression. By and large, however, the theory of estimation and forecasting presented within this text is fairly classical in nature; the authors rely heavily on the least squares criterion of estimation and evaluation of models for economic time series. Relatively little time has been spent on estimation and forecasting techniques based on alternative criteria which have received increasing attention in the recent statistics and econometrics literature. A particularly interesting example of such work is the recent book by Bibby and Toutenburg. Their analysis starts from the observation that classical statistical forecasting techniques usually are based on accurately estimating the expected value of the time series of concern. By constructing models predicated on estimating the actual value of the time series, Bibby and Toutenburg are able to derive what they term "improved" estimators and hence "improved" predictors. An example of such estimation and prediction procedures is the class of homogenous estimators and predictors. The optimal homogenous estimator in the general linear model can be shown to be a combination of the estimators obtained by the ridge regression procedure and generalized least squares. In many cases, these estimators will perform better than least squares estimators given a different criterion for evaluating model forecasts. This work can be closely aligned with that of Hoerl and Kennard and others on ridge regression and biased estimation. Incorporation of this material into the text by Granger and Newbold would have made an interesting bundle of tools for the practicing econometrician. Although it cannot be expected that authors include all that has been done in previous work, it is suggested that persons seriously interested in forecasting techniques consider complementing the text by Granger and Newbold with a text placing more emphasis on nonclassical procedures.

Granger and Newbold accomplish all of the objectives set forth in the introduction to this text. Not only do they accomplish objectives, but they do so in a manner most profitable to the reader. Any person interested in either the theory or practical aspects of forecasting economic time series would do well to avail himself of a copy of this book. The authors are to be lauded for both undertaking such a complex task and achieving such excellent results.

Robert G. Chambers
Ohio State University

Reference

Bibby, John, and Helge Toutenburg. *Prediction and Improved Estimation in Linear Models*. New York: John Wiley & Sons, 1977.

Grennes, Thomas, Paul R. Johnson, and Marie Thursby. *The Economics of World Grain Trade*. New York: Praeger Publishers, 1978, 129 pp., $16.95.

World trade in grain is of special significance to the United States at this time in history. Concern over the balance of trade (and payments) situation, pressure to increase domestic grain prices, potential for expansion of exports to the Peoples' Republic of China, and uncertainty created by political instability in the Middle East have focused attention on the nature and behavior of international markets.

Thomas Grennes, Paul R. Johnson, and Marie Thursby provide a timely application of a reduced-form modeling approach for analyzing international trade in grain. A principal objective of the book is to demonstrate the usefulness of a model of this type in forecasting prices and in analyzing certain policy initiatives. It is worth noting that this objective is pursued in a strictly positive vein. That is, judgments regarding social welfare and equity implication of trade and trade policy are clearly avoided.

Chapters 1 and 2 provide an overview of the world grain economy and a historic review of trade relations and policy in trading grain. In general, chapter 1 identifies major wheat exporting and importing regions, historic production levels, and U.S. grain price movements. Chapter 2 lends a historic perspective to issues dealt with in later sections of the book. The authors briefly discuss major changes in grain trade policy, particularly from the U.S. perspective. Much of the policy outlined here and analyzed later relates to protectionist initiatives by various grain exporting nations.

Chapter 3 may well be one of the most valuable portions of this work, particularly for readers interested in questions of modeling methodology. In this chapter, the authors provide a concise, yet informative, evaluation of alternative techniques for modeling world grain trade. They review the relative merits of models ranging across the methodological spectrum from spatial equilibrium models to systems dynamics models. A brief discussion of the appropriate application of several modeling formats between these extremes is included. This chapter presents some interesting insights into tested modification of standard modeling techniques aimed at improving their usefulness in analysis of international trade.

Grennes, Johnson, and Thursby have chosen to use the Armington-IMF model for forecasting trade flows and price movements (chaps. 4, 5). The model is used to analyze the price and flow of impacts of changes induced from the supply side and from particular unilateral policy initiatives. Principally, the model is applied to the international wheat market. However, chapter 6 takes the reader through the model as adopted for trade in rice and coarse grains.

The Armington model is not without its faults.

First, several assumptions might be criticized as overly simplistic. This, however, is a perpetual problem encountered in modeling a market as complicated as that for international trade in grains. A more severe criticism of the model is that, in some respects, it fails to perform as well as a much more naive approach. The authors recognize and discuss its shortcomings.

No matter how one views the viability of the Armington model, it is important to note that the authors have attempted systematically and quantitatively to evaluate several trade policy alternatives (chaps. 7, 8). Herein lies the real significance of this book. It presents methodology to address very real and critical contemporary economic issues. The book can act as a departure point for those interested in pursuing additional econometric analysis of the world grain market.

Michael V. Martin
Oregon State University

Hyer, Edgar A., and John A. Rogalla. *Farm Management*. San Luis Obispo, Calif.: Farm Management Publishing Co., 1978, viii + 271 pp., price unknown.

The authors seek to provide a textbook for standard principles of farm management courses. The implication is that this represents an introductory or first exposure farm management course. The book is divided into six parts: (*a*) Introduction—a historic treatment of American agriculture; (*b*) Measuring Financial Success—farm records and income measures; (*c*) Finding Strengths and Weaknesses—efficiency factors; (*d*) Changing the Farm—use of the farm budget and linear programming to evaluate economies of size, input combinations, and choice of enterprises; (*e*) Operating the Farm—management of labor, equipment, the acquisition of capital and input and product marketing; and (*f*) Public Influence in Farming—taxes, farm programs, and environmental and safety programs. The authors indicate that students with six quarter-hours of economics should be able to understand the economic concepts utilized.

There are some problems with using this book as a text in an introductory farm management course. As an example, chapter two considers farm record systems without providing illustrations or examples. This material will have little meaning to the student with no background in accounting. The authors state that the chapter is not complete enough for use in a separate farm records course. However, without illustrations and problems, the material will not be useful to most students. Other sections also lack adequate illustration of the concepts. Instructors adopting this text will find it necessary to provide a substantial number of illustrative examples and problem sets.

The farm records and analysis section (part 2) would have benefited from elaboration on analyzing changes over time. The very common act of "spreading" financial statements was not covered. Use of records as an ongoing control mechanism should be a part of any contemporary farm management textbook. Profit measures in this section and investment decisions in later parts of the book should be based on after-tax results. After-tax treatment was finally mentioned in chapter 14 under the discussion of milk quotas. The omission of "cash-flow" budgeting in the farm budget chapter is a serious exclusion considering the increasing importance of capital management in agriculture.

The inclusion of a chapter on linear programming is desirable, but the type of presentation could be improved. The uninitiated will not be able to follow the material and even those familiar with LP may find the chapter confusing.

Part 5 on operating the farm contains the four best management chapters of the book. The chapter on labor provides explicit treatment of managing with organized farm labor. The separation of obsolescence and use in treating depreciation is presented effectively in the machinery chapter. Failure to treat machinery replacement was a significant omission from this chapter. The capital management chapter would have been strengthened with some treatment of risk.

The part entitled "Public Influence in Farming" (part 4) added an important dimension missing from many farm management texts. The chapter on taxes was well done and covered both income and estate taxes. The authors were rather careful to avoid materials which could be invalidated by changes in IRS regulations. The chapter on farm programs provided a good example of use of budgets by a farmer in deciding upon participation or nonparticipation. The modest discussion of income distribution issues related to federal programs was good. The concluding chapter on environmental and safety regulations was a useful inclusion, but the authors need to be more careful of statements related to what farmers are permitted to do because of differences among state laws and regulations.

In summary, the book covers most of the correct topics at an introductory level. Classroom use will require extensive support in terms of illustrations and examples. There are areas which will require expansion beyond the coverage in this book. It is unfortunate that the book contains a large number of typographical errors which detract from the presentation. The search for an ideal textbook for the introductory farm management course must continue.

Leroy F. Rogers
Washington State University

Lave, Lester B., and Eugene P. Seskin. *Air Pollution and Human Health*. Baltimore, Md.: Johns Hopkins University Press for Resources for the Future, 1977, xx + 368 pp., $22.50.

Lave and Seskin analyze the effect of air pollution on human mortality. The book is the culmination of a ten-year research effort and is written for government decision makers, public health service officials, and other groups concerned with environmental protection.

Controlling for air pollution, socioeconomic characteristics, and meteorological conditions, the authors analyze 1960 mortality data from up to 117 Standard Metropolitan Statistical Areas. The analysis is replicated using 1961 and 1969 data and generally confirms the 1960 results. Regression is used extensively with cross-section, time-series, and pooled data. A single equation model is employed throughout, with several alternative functional forms examined. The authors decided to rely on the linear specification because of its simplicity and ease of interpretation. Although several air pollution variables are analyzed, the major focus is on suspended particulates and sulfates. These two variables are, for the most part, consistently significant, implying an association between air pollution and mortality.

Lave and Seskin draw three main conclusions from their analyses: (*a*) There is a significant association between specific air pollutants and death rates across U.S. metropolitan areas. Although multivariable analysis (author's term) cannot prove causality between air pollution and mortality, the consistent statistical significance between the two factors (plus findings of other studies in the epidemiological literature) lend support to the concept of causality.

(*b*) A benefit/cost analysis supports the abatement of air pollutants from stationary sources (mainly sulfates and suspended particulates). The statistical analysis of mobile source pollutant effects on human mortality is inconclusive. Based on these and other findings, the authors concluded that benefit/cost analysis does not support the current federal program on mobile source emission control.

(*c*) Setting national air pollution control standards to protect the "public health or welfare" is not warranted. Standards should be set on the basis of benefit/cost tradeoff analysis.

A number of criticisms can be leveled at the Lave and Seskin approach (failure to include certain explanatory variables in the models, need for better explanations of why certain variables are statistically significant but have the wrong sign, or why certain variables are included in the models in the first place, etc.). This short critique will focus only on those items which may question or support the study's findings or conclusions.

Overall, the first conclusion is supported by the analyses. Lave and Seskin ran a number of regressions to estimate the association between air pollution and mortality. The regression results are consistently affirmative and are well documented. As mentioned above, however, some of the findings could be discussed in more depth.

Conclusion two is not entirely supported by the authors' analyses. Problems with multicollinearity and probable use of air pollution data containing random measurement errors are the reasons. The issue of multicollinearity is discussed first.

The authors discuss their concern for multicollinearity and its potential for distorting the estimated coefficients. Yet, in part of the analysis, they ignore the multicollinearity problems, or undertake forms of analyses that enhance the problem. The authors omit certain socioeconomic variables from their models. They dismiss these variables by stating that they are concerned primarily with omitted variables which will bias the association of air pollution with mortality (p. 22). Lave and Seskin ignore the fact that poor nutrition and medical care, for example, may be associated with lower socioeconomic status, which, in turn, may be connected with higher levels of air pollution. The poor are likely to live in more polluted areas.

The authors' benefit/cost analysis supporting control of stationary source emissions is questionable. The regression equation (p. 31) used to develop the benefit estimates had significant multicollinearity among the air pollution variables. The resulting nonsignificance of the estimated air pollution coefficients made their interpretation difficult (p. 36). To derive the benefit estimates, the authors summed the elasticities of insignificant, unreliable coefficients. The validity of this process is debatable.

Lave and Seskin appear to have used measures of nitrogen dioxide in their analysis based on the Jacobs-Hecheiser (J-H) method. The J-H method was the initial EPA reference for nitrogen dioxide and was used widely in the United States. However, in 1972 it was found that the method produced significant, random errors. Although the authors recognize the problem (p. 6), they appear to use the J-H values anyway. Since J-H data are unreliable, so are conclusions which are sensitive to these data.

One can chide the authors for advocating use of benefit/cost analysis as a sole criteria for setting environmental standards. It can be argued that EPA should perhaps place more emphasis on benefit/cost analysis. However, there are many environmental effects that cannot be economically quantified, and there are other considerations (political, for example) to account for. At best, benefit/cost analysis should serve as one input into the decision-making process.

Lave and Seskin's treatment of air pollution and human mortality is comprehensive, considering the limited data bases. Their study should be considered as another contribution to the increasing body of literature relating air pollution to human health. One should recognize that their work is dated. This statement is not meant to detract from the research's contribution. When some of Lave and Seskin's initial findings were reported almost ten years ago, they were significant. However, the state-of-the-art has advanced significantly since

then. One would anticipate that future research will build upon their work to yield more precise, reliable estimates. "The regulators cannot wait until the scientists provide all the answers, for there will almost always be some degree of uncertainty in some parts of the data" (Costle, p. 3).

John A. Jaksch
U.S. Environmental Protection Agency,
Oregon State University

Reference

Costle, Douglas M. "Protecting the Public Health." *EPA J.*, vol. 5, no. 3.

Meister, Anton D., Carl C. Chen, and Earl O. Heady. ***Quadratic Programming Models Applied to Agricultural Policies*. Ames: Iowa State University Press, 1978, 110 pp., $6.00.**

This book describes the adaptation of Iowa State's national agricultural model to a quadratic programming format. It contains eight chapters, the first two of which describe and contrast linear and quadratic programming models while the remainder contain the empirical specifications and applications of the Iowa State model.

In Chapter 1, the information needs of policy analysis are discussed and the information generated by linear and quadratic models is contrasted. Chapter 2 contains mathematical specifications of the linear and quadratic models, the self-dual quadratic models and quadratic models with both symmetric and asymmetric demand matrices. For each model the presentation includes both its optimality conditions and the economic interpretation thereof. This is the best chapter of the book. It provides a brief but rigorous overview of spatial programming models which would be useful in graduate courses in which there is too little time to investigate a detailed treatment like Takayama and Judge.

In Chapter 3, the structure of and data generation procedures for a quadratic model of U.S. agriculture in 1980 are presented. The model represents 10 consuming and 103 crop- and livestock-producing regions within the United States as well as international demand for several commodities.

Results from the solution of a free market model are presented in Chapter 4 for 1980, and contrasted to actual 1965 data. The results include national weighted-average prices (deflated to 1965 dollars), production and consumption, as well as regional data on acreage and/or production; shadow prices on constrained resources; labor, capital and fertilizer requirements, unused land and livestock capacity; and interregional transfers.

In Chapter 5, the implications to domestic agriculture of increased exports of wheat, feed grains and soybeans are investigated by increasing export requirements in the model's constraint set and comparing the resulting solution to the original 1980 solution.

Chapter 6 contains an analysis of a support price policy. The analysis is accomplished by forcing 1975 (deflated to 1965 dollars) target prices for grains and cotton into the 1980 model as minimum prices. No account is taken of either the loan rate or set-aside programs. The results are increased production and surpluses of grain, decreased livestock production, and increased livestock prices.

In Chapter 7, restrictions on fertilizer applications are imposed on the 1980 model to reflect concerns about environmental quality.

Chapter 8 contains a discussion of limitations of the model and data used. The authors conclude that several limitations exist but "the results . . . seem, in general, reasonable and consistent . . ." (p. 99).

I was left with some qualms and questions about the empirical analysis. First, there is no attempt to validate the model against an historical time period. There is, of course, a controversy over validating normative models (see Schaller). In my view, specification of a normative model is neither more nor less than specifying an hypothesis about economic behavior. It should be tested. In this case, the opportunity existed since the data on which the model is based are drawn from the 1960s and a reasonably free market existed in U.S. agriculture after 1972. An historical validation would have allowed for a diagnostic analysis of deviations between real market and the model solution which would have been helpful in either improving the model or in understanding real world behavior.

There are some deviations. First, the free market solution for the equilibrium live hog to live cattle ratio is .54. Over the past quarter of a century, the historical ratio has been approximately .75. Second, the fed cattle price from the 1980 solution (deflated to 1965 dollars) is $27.29 per hundredweight, the price of corn is $.86 per bushel, and the price of 400-pound feeder calves is $19.40 per hundredweight. If the fed cattle and corn prices are inflated by a factor of two and one-half, they are similar to nominal prices for those two products in early 1979 ($68.23 per cwt. and $2.15 per bushel, respectively). Multiplying the feeder calf price by 2½ gives $48.50 per hundredweight. This does not strike me as a reasonable approximation of equilibrium prices. Third, in the 1980 solution, the Pacific and Mountain states are projected to produce no fed beef. This is surprising, given that some fairly significant cattle feeding states are included in these regions. It is even more surprising that there is also no idle fed beef capacity for the Mountain states—which would appear to be an error in logic.

There are additional results which disagree with reality. The number is sufficient to cause skepticism about the model and to expect an explanation from the authors. None is given.

The reasons for these deviations from reality might lie in the model's specification. Again, several questions can be raised. First, export equations are included only for cattle, hogs, and soybean oil. International trade in the remaining commodities is represented by fixed constraints, on the ground that there are "deficiencies in foreign demand data" (p. 98). Other researchers have had reasonable success in estimating trade equations. At least a limited amount of reliable analysis would improve the interaction of the United States with the world market in the model.

Second, the domestic demand matrix—which is crucial in multicommodity models—is obtained by combining Brandow's elasticities with average annual regional prices and quantities demanded during 1963–65 to estimate price coefficients. Then the intercepts are adjusted using time trends to obtain demand functions for 1980. One wonders why George and King's later estimates were not used or even referenced. Also, one wonders why only the intercepts are adjusted and why with time trends. Why are not the intercepts adjusted for changes in income and population and the slope coefficients adjusted for changes in income?

A final comment concerns the analysis of the target price policy. The logic of a higher-than-equilibrium support price for grains resulting in reduced production and increased prices for livestock escapes me. I would have expected the opposite impacts on the livestock sector since increased grain production would drive down market-clearing grain prices. What is not clear from the book is whether the analysis was intended to reflect the true impact of a pure price support policy or whether it was merely a modeling exercise. If the latter, it is not very useful. If the former, it is conceptually incorrect.

In either case, one wonders (since no indication is given) whether the model is sufficiently flexible to analyze the policy correctly and whether it will accommodate more complex policy situations like the loan rate or set aside programs.

Larry J. Martin
University of Illinois

References

George, P. S., and G. A. King. *Consumer Demand for Food Commodities in the United States with Projections for 1980*. Giannini Foundation Monograph No. 26, University of California, Berkeley, 1971.

Schaller, W. Neil. "Estimating Aggregate Product-Supply Relations with Farm Level Observations." *Production Economics in Agricultural Research*. Urbana: University of Illinois Press, 1966.

Takayama, T., and G. G. Judge. *Spatial and Temporal Price and Allocation Models*. Amsterdam: North-Holland Publishing Co., 1971.

O'Rourke, A. Desmond. *The Changing Dimensions of U.S. Agricultural Policy*. Englewood Cliffs, N.J.: Prentice-Hall, 1978, xiii + 241 pp., $10.95.

This book was written for use as a text in a one-semester undergraduate course. According to the author the "book attempts to give the reader some insight into both the permanent and changing elements of U.S. agricultural policy and some basis for evaluating the impact on the nation and the world of current laws and future proposals" (p. 2).

The book, divided into ten chapters, contains the list of topics one would expect to find in an undergraduate text. It opens with definitions and reasons for studying agricultural policy. Chapter 2, appropriately entitled "Cast of Characters," describes both traditional and new groups in the policy process, with a brief description of how policy is formulated. This is followed by the economic and social background as it affects agriculture (chap. 3), a review of how economists explain farm policy needs (chap. 4), and characteristics of demand, supply, and the marketing system (chap. 5). Chapter 6 reviews agricultural policies of the 1970s with emphasis on changes in the forces affecting agriculture. Chapter 7 puts U.S. agriculture in the rapidly changing world context. "Poverty in Agriculture" is the subject of chapter 8. The chapter (9) on beliefs, values, and goals is a rambling review of materials which can be found with better organization in other books (Hathaway). This chapter also includes a section entitled, "A Framework for Future Agricultural Policy," which more appropriately could be called a policy prescription.

In addition to discussion of the traditional participants, chapter 2 contains relevant information on other organizations not usually recognized as being important in the policy process. Although the chapter is informative, it is long and becomes somewhat tedious in discussion of USDA agencies.

Chapters 3, 4, and 5 might well have been organized in a different way. Chapter 5, with its emphasis on characteristics of agriculture, logically could have followed the chapter on the economic and social environment. This would have provided more basis for understanding the sources of policy problems and why economists try to explain farm policy needs.

The chapter on how economists explain farm policy needs is, as stated, a review of explanations offered by others. It fails to provide a comprehensive framework to the student for analysis of the performance of agriculture and what might be expected of it. This reviewer would like to have seen more emphasis on important concepts in policy such as opportunity costs, rates of return to resources, resource allocation, income comparisons, externalities, and the role of prices in a marketing system. A logical discussion or brief review of these concepts would enable the student to understand policy problems better and be better able to evaluate past policies and policy proposals, an objective which the author stated at the outset of the book.

In places the book contains errors of fact and analyses which are not well supported. For example, the Cooperative Farm Credit System, the Farmers Home Administration, and the Commodity Credit Corporation are classified as public agengies which supplement and compete with private credit institutions such as banks and insurance companies (pp. 131–33). Classifying the Federal Land Banks and the Production Credit System (no mention is made of the Bank for Cooperatives) as public agencies serves no useful purpose and would be considered in error by many, especially the personnel and borrowers of these institutions. The Cooperative Farm Credit System was originally capitalized with federal funds, but the operating units have been fully borrower-owned since 1968. The operating units are supervised by the Farm Credit Administration, an independent government agency whose expenses are paid by the operating units. Loan funds come from the sale of bonds to the public and do not represent government loans as is implied by the author.

The analysis as to why this system was needed is also subject to a different interpretation. Farm businesses are not any poorer credit risks than other businesses. The amount of individual credit needs, timing of availability of funds for repayment, and access to loanable funds, were reasons for development of the cooperative credit system, not that farmers were poor credit risks. Statements in this section are inconsistent. Agriculture is considered to be a "very profitable industry . . ." (p. 131). Two pages later one encounters the statement, "a farmer must earn 9 percent on borrowed capital . . . in an industry which rarely earns more than 1 percent on all capital employed." In addition to lack of consistency, the analysis is not complete.

O'Rourke's policy framework is essentially a free market approach except that a group of "core" farmers would be provided a guaranteed minimum income base. Core farmers are defined as commercially viable farmers chosen on the basis of competitive criteria. If government desired to stimulate supply, it should use a forward contract price. Welfare programs should be taken out of the U.S. Department of Agriculture. His program would also include removal of uneconomic regulations within agriculture or without, and general promotion of competition. The program would include extension to agriculture of the same bargaining rights as unions now possess. This last proposal seems inconsistent with the rest of the approach; however, it is consistent with the viewpoint expressed earlier that other economists tend to overlook many of the imperfections in the markets.

The organization of this book is appealing for classroom use. Each chapter is divided into sections which are followed by key words, central concepts, and study questions. The questions cover material not included in the book and should stimulate discussion and further study. The central concepts part is useful but needs further work in any subsequent edition because several concepts are not clearly presented, e.g.. aggregate effects (p. 7), technology (p. 57), and diminishing returns (p. 90). The book includes a comprehensive index which is of benefit to the reader, and the final chapter includes a comprehensive list of readings which appears to be appropriate for an undergraduate class.

The principal limitations of this book have been illustrated. Possible errors of fact and interpretation have been pointed out. On the other hand, it has many positive attractions, including a style of writing which makes for easy reading. Since it is one of the most up-to-date books available in an area where books quickly become dated, instructors will want to consider it as a text for an undergraduate course and supplement it with sections of other books and other interpretation of parts of the subject matter.

Bob F. Jones
Purdue University

Reference

Hathaway, Dale E. *Government and Agriculture, Public Policy in a Democratic Society*. New York: MacMillan Co., 1963.

Palmer, John L., and Joseph A. Pechman, eds. *Welfare in Rural Areas: The North Carolina-Iowa Income Maintenance Experiment*. Washington, D.C.: The Brookings Institution, 1978, xiii + 273 pp., $11.95, $4.95 paper.

During the three-year period 1970–73, some 700 low income farm and nonfarm families in rural areas of North Carolina and Iowa participated in a social experiment to help determine the impacts of a negative income tax (income maintenance) program. Impacts which the experiment was to determine included those on hours worked, earned income, payments received, consumption, asset accumulation, job mobility, school performance, and psychological well-being. One control plus five treatment groups were used; treatments varied by the level of guaranteed income and the benefit reduction or tax rate. The rural experiment, which complements similar urban experiments, was conducted by the Institute for Research on Poverty of the University of Wisconsin, and results are published in a final report from the Institute. The book under review is a product of a 1977 conference sponsored by the Brookings Institution to review the experiment, and evaluate both policy and research implications.

Individual conference participants and chapter contributors include: Larry L. Orr, an overview of the experiments and findings; D. Lee Bawden and William S. Harrar, the design and operation of the

experiment; Harold W. Watts and D. Lee Bawden, issues and lessons of the experimental design; Finis Welch, labor supply response of farmers; Orley Ashenfelter, labor supply response of wage earners; Robert T. Michael, consumption effects; Michael T. Hannan, noneconomic outcomes; G. Edward Schuh, policy and research implications; Marvin M. Smith summarizes the conference discussion. Comments by others follow each chapter.

Policy Implications

Few policy implications from the report or the underlying research go unscathed by the rigorous economic and sociological debate. The most damning criticism by the authors is leveled at the experimental design: rigor was sacrificed for budgetary and time considerations. A sample of deficiencies include: a sparsity of families in particular treatments, truncation of the sample, sample selection from only two states, use of a scattered sample approach, and perhaps most important, limiting the experiment to three years. Rationale for the criticisms is vividly portrayed.

Theoretical underpinnings of the original studies are also questioned: general equilibrium effects are not adequately addressed, human capital formation goes unmeasured or poorly measured, the culture of poverty theory is investigated as an afterthought, the definition and farmers' report of income is challenged, and key variables such as the accounting period and the reporting period are not included in the analyses. As one participant indicates, the cost of a national program (one of the key effects of interest) would vary by billions of dollars depending upon the accounting period chosen.

Although most of the criticism goes unanswered, or at least little consensus derives from the proceedings, some may wish to take results of the original research at face value since they are, presumably, the best available. Key findings and implications include: (*a*) for both farm and nonfarm families, there is little change in the work and earnings of the husbands while wives and dependents reduced their work and earnings. This result implies that there is no need to include a work requirement in a tax program and that housewives may devote more time to the care of children and thus nurture human capital formation. The decrease in earned family income implies that total program costs are substantially more than direct transfer payments, and must be recognized in policy considerations. (*b*) Nutrition was enhanced in North Carolina but not Iowa. Some argue, then, that since diets were relatively poor in North Carolina, the tax program is a viable substitute for current food subsidy programs. (*c*) Psychological well-being was not affected and therefore concern that a tax program would diminish self-respect is unfounded. (*d*) The lack of accuracy of income reported by farmers and a failure of participants to understand the program will require administrative action.

Research Implications

Are large-scale, multiyear social experiments an efficient way to obtain policy information? This all important question goes largely unexplored. However, Metcalf, who participated in most of the experimental design, states (p. 76): "As a general strategy, I believe a social experiment of this sort cannot be justified unless the issue at hand is regarded as critical enough to warrant a much larger sample than was funded for the rural experiment. An effective experiment is an extremely expensive undertaking. Unless society is willing to bear the cost, an alternative research strategy should be used."

Aside from the preceeding deficiency, the book is indeed rich in research implications and is "must" reading not only for those who would participate in future social experiments at the national level, but also for those who gather primary data from much smaller populations. Information and implications at several levels of the research process abound. (*a*) Researchers are to use more of their resources to identify the socioeconomic goals of society before beginning research on what just may be a nongoal or nonissue. (*b*) Many aspects of theory are treated either in a critical way by testing theory against the data, by way of explanation, or by way of exhortation for inclusion in future research. Theories treated pertain to conventional labor supply, the new household economics, life cycles, the culture of poverty, general equilibrium, and distribution. (*c*) Experimental design issues, including dispersement of sample, site selection, sample size, sample characteristics, and duration of the experiment are treated, oftentimes in depth. (*d*) Some attention is paid to questionnaire design, content, and administration. The difficulties of defining and then eliciting reliable information on such a basic variable as income is aired in gory, but necessary, detail. And the importance of considering the Hawthorne effect (the effect on dependent variables caused by contact between the staff of the experiment and the participants) is brought forth.

The book is both well-edited and well-written.

Harry W. Ayer
Natural Resource Economics Division,
ESCS, USDA

Wortman, Sterling, and Ralph W. Cummings, Jr. *To Feed This World.* Baltimore, Md.: Johns Hopkins University Press, 1978, xiv + 440 pp., $25.00.

This book addresses the important questions of world hunger and poverty from a decidedly pragmatic and action-oriented perspective. As the authors state in the introduction, "this report has been prepared from the vantage point of individuals asso-

ciated with the Rockefeller Foundation and the International Agricultural Development Service," two institutions that have been and are actively involved in the development of new agricultural technologies and in the promotion of rural development programs. As such, the book fundamentally consists of (*a*) a description of the world food situation and of the history of the Green Revolution, foreign assistance in agriculture, and specific programs to increase food production and (*b*) the definition of a strategy to accelerate increases in agricultural production and rural incomes.

The departing point for the authors' proposal is the conviction that "for the first time in history we now have an opportunity to deal effectively with the problem" (p. 6) and that this gives "a firm basis for hope that hunger and the associated poverty can be eliminated" (p. xii). This opportunity is based on two factors: the growing "will" of the world's leaders to deal with the issue and the availability of a new technological capability to increase production. The technology-led strategy which the authors propose consists in organizing forced-pace campaigns to modernize peasant agriculture and bring it into the market economy. As they say, "there are two sides to the food problem: one is to increase production; the second is to create purchasing power among the hungry. The effort to increase crop and animal production on the millions of family farms around the world gets at both sides of the equation. It is the only approach which does" (p. 8). Family farms are thus seen to be both the source of the bulk of food supplies (p. 6) and the principal receptacle of poverty and hunger.

The strategy to feed this world consists of two steps: first, to implement land reform where necessary in order to create an agrarian structure of privately owned commercial family farms since "in the absence of effective agrarian reform the results will never reach full potential in terms of either production or income distribution" (p. 9); second, to launch a three-component approach consisting of commodity-oriented production programs, defined-area campaigns (regional development), and synchronized and reoriented government services. These programs are aimed at making technology, instruction, modern inputs and credit, and markets available to smallholders. And they are to be backed by a generous inflow of foreign assistance.

The book has a definite flavor of technological determinism: "We place an especially high premium on the role of technology and the importance of research" (p. xiv). The authors are obviously well-informed and long-time participants in that area of knowledge, and this gives a distinct interest to the book. Thus, the organization of research, the development of new technologies, and the management of diffusion programs are discussed in detail. This will prove useful to readers who want to be familiarized with the history and implementation of Green Revolution technology.

The main shortcoming of the book, however, is that it describes and prescribes but without presenting an explanation of the hunger-poverty crisis in its economic, social, and political causes over the course of history. As a result, the proposed strategy for change is in my view largely utopian and so is the announced basis for hope.

Clearly, the hunger-poverty crisis is not a technological or natural problem but a social product. Key elements of an explanation are rooted in such factors as the economic and social class structure created by colonialism, the economic logic of cheap labor and cheap food policies, the tremendously uneven distribution of the land, the diversion of some of the best lands for plantation and export crops, and the increasing reduction of peasants to the mere function of a cheap labor reserve. In this context, poverty and hunger are not the isolated products of traditional agriculture but the results of a complex set of exploitative social relations.

A strategy for change needs to start from an understanding of these complex economic, social, and political realities and must be oriented at changing their root causes. A program of technological modernization will otherwise almost inevitably lead to increased inequalities and accelerated displacement of peasants. That political change is essential is briefly acknowledged by the authors when they observe that "most relatively successful land reforms have been carried out when the normal political process was suspended" (p. 281). In the strategy they outline, land reform is an essential precondition. Yet, the strategy of forced-paced, technology-led modernization is proposed to avoid social change: "There is no time to lose. The incentives for action are clear: They involve urgent matters of political stability and national security, as well as economics" (p. 3). Social change or status quo? While need for the first is eventually acknowledged, the second is put forward as a goal: "Government leaders are increasingly aware that, unless they take steps to develop their rural areas through widespread involvement of the rural poor, they will likely face unrest, violence, even revolution" (p. 3). Since the latter is to be avoided, forced-paced modernization of peasant agriculture is suggested. The reader is thus left with the unresolved contradiction that social change is needed to create the preconditions for accelerated and socially beneficial agricultural development while agricultural development is simultaneously seen as an urgent need to avoid social change.

In conclusion, the book offers important pragmatic insights into the processes of generation and diffusion of technological change in agriculture. For readers who believe that the hunger-poverty crisis is principally social and political, the book will, however, appear short of out'ining an effective program to feed this world.

Alain de Janvry
University of California, Berkeley

American Journal of Agricultural Economics

Volume 61 Number 4

November 1979

AMERICAN AGRICULTURAL ECONOMICS ASSOCIATION

The *American Journal of Agricultural Economics* is published five times a year (February, May, August, November, December) by the American Agricultural Economics Association. Prior to 1968, this *Journal* was the *Journal of Farm Economics.*

Printed for the AAEA by Heffernan Press, Inc., Worcester, Massachusetts, USA.

Second class postage paid at Lexington, Kentucky, and additional mailing offices, Pub. No. 019500.

Editorial Policy

The purpose of the *Journal* is to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscripts should have a relationship to the economics of agriculture, natural resources, or rural and community development. Contributions, methodological or applied, in the business, extension, research, and teaching phases of agricultural economics are equally encouraged.

Editorial Communications

All manuscripts and editorial correspondence, except as noted below, should be addressed to the editor, V. James Rhodes, Department of Agricultural Economics, Mumford Hall, University of Missouri Columbia, MO 65211

Communications concerning book reviews and books submitted for announcement in the *Journal* should be sent to the book review editor, Herbert H. Stoevener, Department of Agricultural Economics, Oregon State University, Corvallis OR 97331.

Articles

Agricultural Pollution: The Economics of Coordination

Basil M. H. Sharp and Daniel W. Bromley

Institutional design is the major obstacle in reducing agricultural pollution. Cost sharing is being proposed for encouraging best management practices. Two models, one representing an agricultural firm and the other a management agency, are used to illustrate the flexibility and analytic capacity that agencies must have in determining the cost-sharing rules that apply to on-farm abatement practices. Off-farm investment opportunities should also be considered. If water quality is to be improved, these institutional arrangements will need the capacity to generate information, adapt to changing conditions, and reconcile the conflicting incentives of other programs.

Key words: agricultural pollution, coordination, input demand, institutions.

Agricultural activity has been cited as one of the leading contributors to the nation's water quality problems (General Accounting Office). It is now apparent that the federal government will not utilize regulatory constraints as a policy device for achieving the goals of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). This direction echoes much of the sentiment expressed at the hearings before the Senate and House of Representatives on bills to provide for the maintenance or enhancement of the quality of water in rural areas (U.S. Congress 1977a, b). It is clear that the formulation of policy instruments at the federal level to enhance water quality will proceed with the minimum interference of individual farmer's activities, thereby reflecting the Jeffersonian doctrine about preserving the independence and virtues of small-scale farming.

Currently, policy makers are attempting to strengthen financial incentives for inducing voluntary participation in conservation-oriented practices. The Rural Clean Water Program (PL 95-217), passed by Congress in December 1977, authorized the Secretary of Agriculture to allocate $200 million for fiscal year 1979 and $400 million for fiscal year 1980. These funds were to be distributed through cost-sharing programs under the direction of the Soil Conservation Service (SCS). Although this program was not funded for fiscal year 1979, Congress intended the funds to have been in addition to the regular Agricultural Stabilization and Conservation Service (ASCS) and SCS programs which received appropriations of $456 million and $497 million, respectively, for 1979 (*Congressional Quarterly Weekly Report*).

Agricultural pollution abatement programs also are being developed at the state level. For example, the authority for water quality management in Wisconsin rests with the Department of Natural Resources and, while major regulatory and grant-in-aid programs focus on point sources, it has been recognized that nonpoint source abatement also must proceed.

The Methodological Setting

A conventional benefit-cost formulation of the environmental quality problem is hampered by the lack of weights (prices) to transform the benefits and costs of water quality into the metric of other economic objectives such as agricultural production. Hence, the usual approach is to utilize a water quality, or a surrogate on-farm, standard as one of the determinants of the feasible set within an optimizing

Basil M. H. Sharp is a research associate and Daniel W. Bromley is a professor in the Department of Agricultural Economics, University of Wisconsin, Madison.

The authors are grateful to Craig Osteen, Wesley Seitz, Earl Swanson, and two anonymous reviewers for assistance on an earlier draft.

This work was funded by the University of Wisconsin Sea Grant College Program under a grant from the Office of Sea Grant, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and the State of Wisconsin.

framework. As Kneese and d'Arge show, the conditions of Pareto optimality through partially adjusted choice can be met and deemed to have the same normative significance as when achieved under "natural" constraints of scarcity, private ownership, and technological production functions. It has been shown that a tax on emissions, set equal to the shadow price of the pollution constraint, is a fiscal measure satisfying the necessary conditions for minimizing the cost of pollution abatement to society (Baumol and Oates).

Agricultural economists have adhered tenaciously to this methodology, to the extent of being tendentious. Effluent charges on nitrogen irrigation returns have been studied by Horner, a tax on crop and pasture land was proposed by Jacobs and Timmons, and a tax on soil-loss was shown by Taylor, Frohberg, and Seitz to result in the most efficient way of achieving the desired reduction in soil loss. Invariably, however, the primary policy instrument that has emerged is not a tax on emissions, rather it is an on-farm standard, such as tons of allowable soil loss, popularized to connote a regulatory approach to agricultural pollution abatement.

These studies have yielded considerable insights into the implications of land use and land management practices for water quality. In addition, they indicate how agricultural operators can adjust their operations to meet tolerable standards, and, in most instances, that costs to the farming community are considerable. However, these studies, and the methods employed, do not adequately address the needs of policy makers. Subsidies are a reality in nonpoint source abatement programs—emission standards are not—and one of the most pressing issues facing local and state units of government is the allocation of scarce federal, state, and local funds in a manner conducive to the attainment of the goals of PL 92-500.

In this context, financial incentives assume the pivotal role of inducing the application of pollution abatement technology on an individualistic basis rather than playing the role of dampening the financial burdens associated with meeting tolerable loadings. More specifically, program design must become more concerned with the sensitivity of the agricultural operator's input demand function for these systems of management with the view of structuring these incentives to achieve the targets of water quality. To this end, a more comprehensive framework for viewing the agricultural pollution process is proposed.

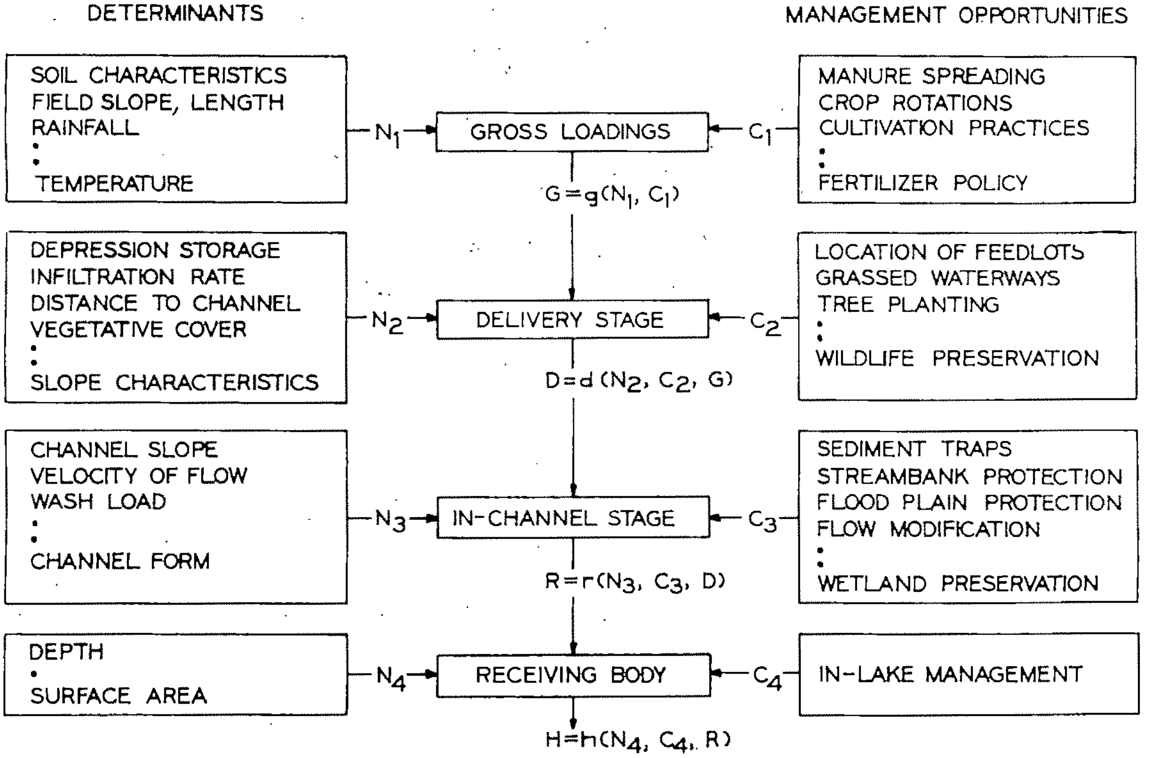
The Pollution Process

The flow diagram in figure 1 traces the stages of the agricultural pollution process, commencing with a set of determinants that initiate it, through the various transformations, to the quality of the receiving body of water. Hence, the first stage relates to practices, such as cropping and manure spreading, which result in the generation of pollutants at the farm level. For example, G may be taken as a vector comprising soil loss, nitrate-nitrogen, ortho-phosphorus, and so on, the levels of which are determined by a vector-valued function g.

These gross loadings are then transported, and transformed during the delivery stage, to a water channel. This stage essentially represents the overland flow phase of delivery and the transformations that occur are represented by the function d. Once in the water channel, the pollutants further interact with the components of the in-channel system eventually to impact the level of water quality entering the receiving body of water, as identified by the function r. Finally, there are a multitude of in-lake phenomena, such as nutrient transport, depth, and surface area, which jointly determine the level of water quality at any particular time.

It is important to appreciate that at each stage of this process there exist a number of management opportunities which can reduce the flow of nutrients, sediments, and other pollutants into receiving waters. These opportunities are identified as control vectors (C_j) with the subscript ($j = 1, \ldots, 4$) referring to the stage at which the controls are implemented. The effectiveness of the controls at any time is determined by the number of "givens" (N_j) in the system, some of which are amenable to change. For example, infiltration rates can be increased over time by using good soil husbandry, channel form can also be modified, but other components such as the distance to channel and channel slope are not so readily changed.

Any analysis that emphasizes adjustments at the farm level necessarily omits many feasible management alternatives. The current focus on best management practices (BMPs) stems from the fact that agricultural activity



Source: Sharp and Berkowitz

Figure 1. The pollution process

augments, and initiates, the flow of pollutants from the land resource. It is the practices of plowing, fertilizing, harvesting, and manure spreading that provide the inputs into a process which is essentially driven by hydrological phenomena. But, the delivery systems and the receiving bodies of water are also amenable to change. Actually, the only requirements placed upon the set of locally determined BMPs is that they be the most effective and practicable means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals (*Federal Register*).

Similar results, in terms of water quality, may be achieved by disrupting the flow of nutrients within the lake proper. For example, aeration, biotic harvesting, lake bottom channelization, and various forms of chemical treatment have been proposed. Also, aeration and mixing systems can be installed in influent water (Speece, Murro and Yeaple). Structural changes, such as diversions, channel grade controls, serrations, sediment traps, and dry ponds can help dissipate the energy of surface runoff thereby allowing the sediment-nutrient complex to settle out. It is conceivable that more predictable changes in water quality may be obtained at a lower cost to society from the use of these alternatives.

One rationale behind the establishment of BMPs lies in the use of *T*-values to determine an upper bound on the management factors in the universal soil loss equation, factors which satisfy the maximum rate of soil erosion permissible for high levels of crop production to be sustained indefinitely (Wischmeier).[1] Soil-conserving systems of management will reduce agricultural emissions to the extent that the soil resource is kept in place and the energy potential of surface water is reduced. These practices therefore serve a dual role in conserving the soil resource and reducing the contribution of agricultural activity to water pollution. However, their adoption under a voluntary program will depend upon the value

[1] The soil loss equation ($A = RK\ LS\ CP$) estimates the average annual soil loss from sheet and rill erosion (A), in tons per acre, for specific combinations of rainfall (R), soil type (K), topographic features (LS), crop system (C) and supporting erosion control practices (P). *T*-values are assigned to a given site expressing a tolerable limit of average annual soil loss. The permissable CP is determined by substituting for A in the equation: $CP = T/R\ K\ LS\ P$. This establishes an upper bound on the set of feasible management practices.

which individual farmers place on the soil and nutrients lost. Current financial constraints may lead farmers to place short-run profits ahead of long-run productivity.

These observations have implications pertinent to abatement programs which rely upon the voluntary participation of individuals for the achievement of water quality goals, the benefits from which are shared by many. Agencies charged with designing programs to control agricultural pollution must appreciate that management opportunities exist outside of on-farm adjustments of the type so commonly found in analyses to date. This is important for the efficient use of public funds; it also has profound distributional implications. In the analysis which follows the control vector **C** will be partitioned as follows:

$$\mathbf{C} = [\mathbf{X}Y]. \tag{1}$$

The vector **X** represents an array of on-farm decision variables which will be referred to as BMPs, some of which may be soil conservation-oriented, and a set of off-farm management options Y reflecting those control measures which may be initiated outside of the farm decision-making environment.

A Framework for Analysis

Institutional change in a socioeconomic system is driven by some concept of desired performance. A society can be said to possess some collective will—however imperfectly defined and acted upon—with respect to such things as the level of water quality, the minimum level of income, and the like. From this view, the policy issue becomes one of finding a set of institutional arrangements which induces behavior on the part of individuals that is consistent with desired performance. Such institutional arrangements may exist through (*a*) the pricing mechanism, (*b*) nongovernment collective action, or (*c*) the government acting as an inducer (cost-sharing), a facilitator (extension education and technical assistance), or an enforcer (regulation). This suggests the following idealized framework: institutional arrangements influence the behavior of individual actors within the system, the aggregate of which leads to certain beneficial and some adverse consequences, thereby influencing judgment of the performance of the system and, so, the institutional arrangements that define its structure, and motivate its actors.[2]

As an illustration, consider the concern in the 1930s with increased soil erosion, along with the attendant problems of blowing dust and silted-in streams and reservoirs. With the expectation that altered behavior would lead to improved performance (less erosion), a new set of institutional arrangements, and an organizational structure, was devised. Specifically, cost-sharing for certain conservation practices was introduced, along with the provision of technical advice. These new institutional arrangements altered the relative benefits and costs of prevailing practices and so rendered new behavior more attractive (profitable) to the individual farmer.

The problem, then, is one of adjusting incentives for decision makers such that the resulting behavior is consistent with, or rather results in, socially desired performance. The essence of efficient policy for dealing with agricultural pollution, where efficiency comprehends not only least-cost abatement at the firm level but also the allocation of scarce public funds, is that of coordinating the actions of two primary actors: the agricultural firm and the management agency. That is, the important question is how public policy can create a set of institutional arrangements which will alter and strengthen incentives for private decision makers to adopt voluntarily systems of production. The complexity of this coordination problem is at once realized when one considers the existence of numerous programs which directly, and indirectly, influence the incentive structure of agricultural firms. Some programs may reinforce existing incentives to incorporate less polluting technology, for example the Agricultural Conservation Program (ACP); while others, such as price support programs, may run counter to the goals of PL 92-500. Signals perceived and patterns of behavior so induced may not correspond with the specific and more narrow objective(s) of any one individual program.

The Agricultural Firm

An agricultural operation may be viewed as a multiproduct firm with the production of q_i

[2] This performance-institutions-behavior model is inspired by the work of Schmid.

achieved by allocating n variable inputs x_{ij} and r fixed factors z_{ir}. The total quantity of the fixed factors Z_r is assumed to be constant and the allocations z_{ir}, among the i products, must satisfy these constraints. However, it is possible to transfer units of these factors from one product to another and readjustments of this nature give rise to switching costs $S(z_{ir})$ (Pfouts). The market price of the products p_i and inputs w_j are assumed constant, although the subsidy rate θ_j on some inputs (BMPs) will lower the market price by $(1\text{-}\theta_j)$. The Lagrangian function for the profit maximization problem is

$$(2)\ L = \Sigma p_i q_i - \Sigma\Sigma w_j(1 - \theta_j)x_{ij} - S(z_{ir}) + \Sigma\mu_r(Z_r - \Sigma z_{ir}).$$

To make the following discussion more transparent without losing any generality, we will assume that the decision variable x_{ij} represents a BMP. An interior solution for this practice is characterized by

$$(3) \qquad p_i \frac{\partial q_i}{\partial x_{ij}} = w_j\,(1-\theta_j).$$

This states the well-known condition that the value of the marginal productivity of the abatement alternative equals its factor price, which in this case is net of the subsidy rate θ_j. Therefore, under these conditions the operator will invoke BMPs commensurate with privately determined benefits.[3] For example, an improved manure management plan will be adopted in accordance with the net value of the nutrients saved. Clearly, any plan that effectively conserves manure nutrients will also reduce pollution loadings; the particular system adopted, however, may not result in the desired level of pollution reduction. For higher levels of pollution reduction, it may be necessary for the agency to increase the subsidy, thereby lowering the relative price of the input which, in turn, lowers the cost of manure nutrients vis-à-vis commercial sources.

Turning to the fixed factors of production z_{ir}, an interior solution is characterized by

$$(4) \qquad p_i \frac{\partial q_i}{\partial z_{ir}} = \frac{\partial S(z_{ir})}{\partial z_{ir}} + \mu_r.$$

Here, the relevance of the fixed factors of production becomes clear because (4) requires an equality to exist between the value of the marginal productivity of z_{ir} and the sum of the marginal switching costs and the imputed value of utilizing Z_r in the production of q_i. Asset fixity is a real consideration in the design of institutional arrangements to reduce agricultural pollution. Any reallocation of these resources inevitably will involve costs; for example, planting equipment may require modification for use within a conservation system of management. Considerations of this nature not only determine the flexibility available for adjustment, but also translate into financial constraints which may alter the responsiveness of agricultural systems to cost-sharing incentives.

As stated earlier, the central concern of the agency is the sensitivity of the farm-firm's input demand function to perturbations in the subsidy rate θ_j. For example, what is the response that will be elicited if the cost-sharing rate is increased from 20% to 50%? To portray this response, the following input demand function will be utilized. It is expressed as a function of output prices, input prices, and unit subsidy rates with subscripts suppressed,

$$(5) \qquad x = x[p, w(\theta)].$$

Neoclassical theory suggests that this function is downward sloping with respect to input price; its elasticity is an empirical question. Current policy models are mandating the use of a BMP, at a level x', to satisfy tolerable loadings. But the critical issue, given the legislative intent not to impinge upon the independence of the farming community, is whether or not the level adopted by voluntary action x^* will lead to socially desirable levels of agricultural pollution. In this setting, government has two options: the price of agricultural products can be altered and/or the price of the inputs can be adjusted to induce the incorporation of BMPs.

The Management Agency

Our model of agricultural production focused upon the alternative aspects of on-farm decision making. In terms of figure 1, only those control instruments which are applicable at stages 1 and 2 of the pollution process were addressed. A management agency can however introduce controls y_{ts}, each costing v_t, at various stages s and it can also influence the adoption of BMPs at the farm level through its choice of the subsidy rate θ_j. Each of these

[3] As used in New York State, a BMP is a conservation practice or management technique that will result in the opportunity for a reasonable economic return within acceptable environmental standards (Loehr et al., p. iii).

instruments will result in administration costs A, a factor which must be recognized in the development of efficient programs.

It will be assumed that the agency wishes to maximize water quality subject to a budget constraint B. Water quality is a multidimensional concept and the functions given in figure 1 are all vector-valued, comprising such indicators as sediment, phosphorus, nitrogen, and toxic chemical concentrations. In view of this, the techniques applicable to multiobjective analysis are necessary (Cohon and Marks). We will assume that a scalar function h represents the notion of water quality.

The agency's principal concern is, therefore, to select that combination of off-farm strategies and on-farm subsidies that yields the highest level of water quality subject to the budget constraint. The Lagrangian for this problem is

$$(6)\quad L = h(y_{ts}, x_{ij}; N) + \beta[B - \Sigma\Sigma v_t y_{ts} - \Sigma\Sigma w_j \theta_j x_{ij} - A\ (\theta_j, y_{ts})].$$

The interdependencies that exist between the agency and the agricultural firm are clear: it is through the choice of the subsidy rate that the agency influences the adoption of the BMP x_{ij}, which in turn impacts the level of water quality h. However, the agency can have more direct control over the level of water quality by employing y_{ts} which influences the off-farm transportation and transformation of pollutants. The relevant equilibrium conditions are

$$(7)\quad \frac{\partial h}{\partial y_{ts}} + \frac{\partial h}{\partial x_{ij}} \cdot \frac{\partial x_{ij}}{\partial y_{ts}} = \beta(v_t + \frac{\partial A}{\partial y_{ts}}), \text{ and}$$

$$(8)\quad \frac{\partial h}{\partial x_{ij}} \frac{\partial x_{ij}}{\partial \theta_j} = \beta(w_j x_{ij} + \frac{\partial A}{\partial \theta_j}).$$

Equation (7) requires the sum of the marginal direct and indirect effects of employing off-farm controls to equal the sum of their purchase price (or marginal factor cost) and the marginal administration costs that result from their use weighted by the shadow price associated with the use of scarce public funds. This condition must hold for all controls at each stage of the process.

Similarly, if a subsidy is to be used as a means of controlling pollution, then equation (8) states that the marginal reduction in pollution must equal the sum of the on-farm expenditures ($w_j x_{ij}$) and the marginal administration costs weighted by the shadow price β.

The agency can, therefore, utilize an indirect means of inducing pollution abatement through its choice of the subsidy rate and it can use a more direct approach by investing in off-farm practices. The rate at which subsidies and off-farm investments can be substituted, while still achieving targeted levels of water quality, should be recognized if scarce public funds are to be allocated efficiently in pollution abatement programs. In addition, the magnitude of the administration costs incurred by the instruments also should be given consideration in program design. Administration costs may be made lower and water quality responses higher and more predictable through the use of off-farm strategies rather than relying solely on subsidies to induce the adoption of BMPs at the farm level.

The Coordination Problem

These two models are coupled, and by the very nature of the interaction between the firm and the agency, some form of coordination is necessary so that the decisions of these actors are in harmony with the goals of society. Subsidies are the driving mechanism in a voluntary program and the problem in designing such programs revolves around synchronizing the supply with the demand for public funds (Mesarovic, Macko, Takahara; Wismer). The essential ingredients of the coordination problem are presented in figure 2. Here, an input demand function for a BMP, as depicted in equation (5), is illustrated in quadrant I. The level of water quality H is shown in quadrant IV to be influenced by the level at which the BMP is adopted at the farm level. Recall from figure 1 that this option corresponds to the early stages of the pollution process and, given that the chemical form and toxicity of pollutants change over time and space, the technical information necessary to establish the causal linkages between these two quadrants is considerable. Different management strategies may be warranted depending upon the proximity of polluting activity to the receiving body of water and agency action with respect to off-farm controls (y_{ts}).

The water quality indicator is then made a function of the cost-sharing rate in quadrant III, with the final connection between the subsidy and the adjusted price of the input being established in quadrant II. Therefore, if H' is the targeted level of water quality, this can be achieved by inducing agricultural operators to employ BMPs at a level x' through a cost-

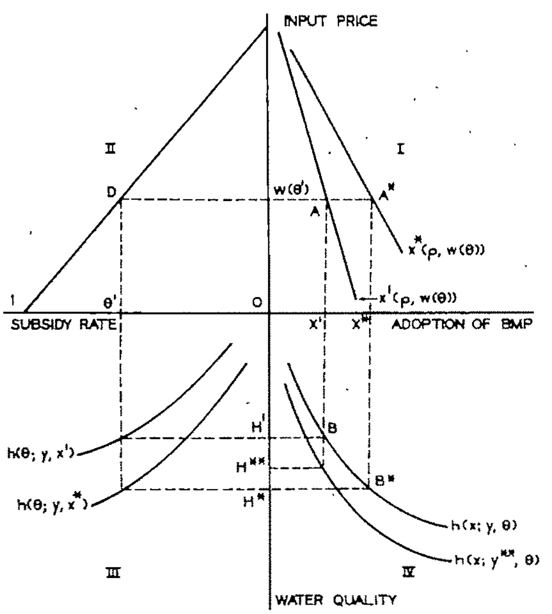


Figure 2. Voluntary abatement programs: the coordination problem

sharing rate of θ'. A lower rate is necessary if the water quality objective is lower.

The agency, however, does have another option: it can invest in off-farm practices y, such as streambank protection and wetland preservation. This form of investment will influence the marginal productivity of on-farm practices in terms of improving water quality and can be extended to include projects designed explicitly for nonagricultural pollution abatement. In figure 2, the effect of increasing these activities from y to y^{**} is shown to shift the water quality indicator resulting in, for example, a higher level of water quality H^{**} and a different marginal productivity for the abatement practice x'.

A number of considerations emerge from this general coordination model which are relevant to the design of agricultural pollution abatement programs. First, the optimal cost-sharing strategy is inextricably linked to the crops that are grown, and, in fact, it is specific to the local conditions of production and the way in which these activities impact water quality. This implies that local control over the determination of these rates is desirable, if not necessary, if scarce public funds are to result in the maximum possible improvement in water quality.

Second, similar cost-sharing rates are likely to induce different responses, in terms of adopting BMPs at the farm level, depending primarily upon the elasticity of the input demand function for the practice. In general, this function is likely to be more elastic, the more readily substitutes can be found. On the other hand, demand will be less elastic, the less important is the part played by cost of x_{ij} in the total cost of production; provided i has a price elasticity exceeding the elasticity of substitution (Ferguson). Therefore, if chisel plowing comprises a small part of the budget for corn production and if the price elasticity of corn exceeds the elasticity of substitution between chisel plowing and a conventional alternative, then the response to changes in the cost-sharing rate will be smaller. A more elastic input demand function x^* is illustrated in figure 2 which results in a higher level of pollution abatement behavior given the same level of cost sharing θ', a shift in the water quality indicator in quadrant III, and a change in the marginal productivity of the policy instrument itself.

It is also possible to illustrate the multiobjective nature of the problem by incorporating a long-run soil productivity goal into figure 2. Assuming that H' is the targeted level of water quality, the issue now becomes whether or not x' exceeds, or is exceeded by, the recommended T-values (x^t) for that soil. If, for example, $x' < x^t$, then the water quality goals will be met if the soil productivity goals are met, *mutatis mutandis*, if $x' > x^t$. While the existence of multiobjectives adds further complications, an early recognition of the dominant concern and the channeling of funds into these practices may assist in the achievement of other objectives. In the event of different agency's being involved, the coordination effort must transcend the boundaries of all actors in order to take advantage of any complementarities that may exist.

This section has highlighted the pivotal relationship that exists between the choice of a subsidy and the adoption of pollution abatement practices at the farm level. There are of course other factors to consider. For example, rules that establish limits on the total subsidy received will influence response as will attempts to discriminate between the components of a BMP that qualify for a subsidy. Therefore, the tailoring of incentives to induce abatement behavior at the farm level is extremely complex. These are issues that economists can address by reorienting programming models to analyze the allocation of scarce public funds within a program which relies

upon voluntary participation. Statistical analyses also may assist in the identification of input demand functions for BMPs. For example, it has been shown that relative prices explain most of the variation in fertilizer consumption (Griliches) and the ACP cost-sharing policies stimulate lime usage at the farm level (Swanson).

Implications for Program Design

The technology capable of achieving substantial reductions in agricultural nonpoint source loadings exists (BMPs); as do the off-farm techniques that can influence the pathways of these pollutants in the environment. However, the distance that exists between the actions of individual farmers and the concomitant impact on water quality has not been fully appreciated by policy makers. The response of water quality to BMPs may not be as great as some off-farm investments—this is a relevant consideration in the efficient allocation of scarce public funds. In dealing with the technical and behavioral uncertainties in a stochastic environment, a common-sense approach would recommend a spreading of the abatement effort between on-farm and off-farm practices.

If the goal of fishable and swimmable water is to be met in reasonable time, the major hurdle is not technology; rather, it is the design of institutional arrangements to encourage the incorporation of this technology into ongoing farming systems. Cost-sharing will play a pivotal role in inducing the adoption of BMPs at the farm level and we are suggesting, based on the above analysis, that an iterative approach be adopted. The institutional arrangement for effecting a program of this nature must have the capacity to (*a*) generate relevant information with respect to performance, (*b*) adapt over time to changing conditions, and (*c*) reconcile the often conflicting incentives of other programs which may dampen the incentives for pollution abatement.

It is almost axiomatic that funds be allocated on a "worst-first" basis during the initial stages of program implementation. Once in operation, the response of the farming community to the incentives and the attendant changes in water quality should be monitored on a periodic basis, at least in representative watersheds. Information of this nature could be obtained in conjunction with the conservation needs inventory that is conducted in most states every five years. In particular, we will need to be able to identify the practices that are most readily adopted, the motivation behind their adoption and what they mean in terms of water quality. These data then become the basis for any adjustments to be made in the incentive structure over time. It is imperative that the agency follow up on the practices installed because the objective is to foster a continuing abatement effort and not a one-shot response.

The adaptive properties of an institutional arrangement will depend to a large extent upon the ability of planners to foresee and prepare for the future. For example, it has been estimated that 1 million acres of high-quality agricultural land is being lost each year to urbanization (Dideriksen and Sampson). Prior to urbanization this land is usually subdivided into smaller part-time operations which crop the land intensively, thereby exacerbating the loadings from these areas. There is little incentive for these individuals to participate in voluntary programs, and special arrangements will have to be made if this form of behavior is to be changed; many counties are considering regulations to deal with this problem. Flexibility is therefore one aspect of adaptation; the other relates to expectations. Expectations are strongly linked to institutional change—decisions made now are based upon what we expect the institutional arrangement to be in the future. This means that there should be a very clear statement about the nature of future changes in the program if a voluntary approach fails to elicit desired behavior. Obviously, participation will be slower if the cost-sharing program is altered frequently—that is, it might prove profitable for farmers to wait for the expected increase in the incentive.

Perhaps the most formidable barrier to be addressed concerns the need to tailor the incentive structure according to local conditions. As indicated by the above analysis, efficient allocation of funds requires differential (discriminating) cost-sharing programs; the response of the farm-firm will depend upon the nature of the technology currently employed, resource availability, and financial considerations. To induce the adoption of BMPs, it may be necessary to vary the per farm limit and the subsidy rate according to local agricultural conditions and water quality. Currently, there does not exist the analytic

capacity to adapt the incentive structure to local conditions.

There are a number of other pressures impinging upon agricultural systems from the national level. The continued policy of stimulating production is leading to more intensive use of land that is marginally suited to cropping, along with a conversion to row crops. The U.S. Department of Agriculture has estimated that between 1972 and 1975, harvested cropland increased by 41 million acres, largely in response to increased foreign demand for grain. This trend, coupled with the loss of high-quality agricultural land, will result in more pollution from agricultural activity over time. Many other programs offer the opportunity for inducing the application of BMPs. For example, the Small Business Administration's loan program and state and federal tax incentives can be tailored to reduce financial constraints. In addition, it may be possible to adapt the wetland and wildlife preservation programs of the Department of the Interior toward meeting the goals of PL 92-500. These avenues have largely been unexplored, yet there seems to exist significant opportunities for reconciling the often conflicting environmental implications of each.

The existing organizational structure for controlling soil erosion would seem to have the potential for playing a significant role in agricultural pollution abatement. In many instances the objectives are complementary and the agencies currently involved have the benefit of experience, particularly in providing technical assistance. However, if the pollution control program evolves as a nationwide fixed cost-sharing effort relying upon voluntary participation, the above analysis suggests that this narrow approach would compromise the efficient use of public funds designated for improving water quality.

[*Received November 1978; revision accepted April 1979.*]

References

Baumol, William J., and Wallace E. Oates. *The Theory of Environmental Policy*. Englewood Cliffs, N.J.: Prentice-Hall, 1975.

Cohon, Jared L., and David H. Marks. "A Review and Evaluation of Multiobjective Programming Techniques." *Water Resour. Res.* 11(1975):208–20.

Congressional Quarterly Weekly Report 36, no. 41, 14 Oct. 1978.

Dideriksen, Raymond I., and R. Neil Sampson. "Important Farmlands: A National View." *J. Soil and Water Conserv.* 31(1976):195–97.

Federal Register, vol. 40, no. 230, section 130.2, 28 Nov. 1975.

Ferguson, C. E. *The Neoclassical Theory of Production and Distribution*. London: Cambridge University Press, 1971.

General Accounting Office. *Report to the Congress by the Comptroller General of the United States*. Washington, D.C., 20 Dec. 1977.

Griliches, Zvi. "The Demand for Fertilizer: An Economic Interpretation of Technical Change." *J. Farm Econ.* 40(1958):591–606.

Horner, Gerald L. "Internalizing Agricultural Nitrogen Pollution Externalities: A Case Study." *Amer. J. Agr. Econ.* 57(1975):33–39.

Jacobs, James J., and John F. Timmons. "An Economic Analysis of Agricultural Land Use Practices to Control Water Quality." *Amer. J. Agr. Econ.* 56 (1974):791–98.

Kneese, Allen V., and R. C. d'Arge. *Pervasive External Costs and the Response of Society*. Reprint No. 80, Resources for the Future. Washington, D.C., 1969.

Loehr, Raymond C., Douglas A. Haith, Michael F. Walter, and Colleen S. Martin. *Best Management Practices for Agriculture and Silviculture*. Ann Arbor, Mich.: Ann Arbor Science Publishers, 1979.

Mesarovic, M. D., D. Macko, and Y. Takahara. *Theory of Hierarchial, Multilevel Systems*. New York: Academic Press, 1970.

Murro, R. P., and D. S. Yeaple. *Engineering Methodology for River and Stream Aeration*. Environmental Protection Agency, Water Pollution Control Res. Serv. Rep. No. 16080FSN, Washington, D.C., 1971.

Pfouts, Ralph W. "The Theory of Cost and Production in the Multiproduct Firm." *Econometrica* 29 (1961):650–58.

Schmid, A. Allan. "Analytical Institutional Economics: Challenging Problems in the Economics of Resources for a New Environment." *Amer. J. Agr. Econ.* 54 (1972):893–901.

Sharp, Basil M. H., and Steven J. Berkowitz. "Economic, Institutional and Water Quality Considerations in the Analysis of Sediment Control Alternatives: A Case Study." Paper presented to the 10th annual Cornell University conference, Rochester, N.Y., 26–28 Apr. 1978.

Speece, R. E. "The Use of Pure Oxygen in River and Impoundment Aeration." Paper presented at the 24th Industrial Waste Conference, Purdue University, West Lafayette, Ind., 8 May 1969.

Swanson, Earl R. "Analysis of Agricultural Limestone Purchases in Illinois." *J. Soil and Water Conserv.* 24 (1969):142–43.

Taylor, C. Robert, Klaus K. Frohberg, and Wesley D. Seitz. "Potential Erosion and Fertilizer Controls in the Corn Belt: An Economic Analysis." *J. Soil and Water Conserv.* 33(1978):173–76.

U.S. Congress, House of Representatives. Hearings be-

fore the Subcommittee on Conservation and Credit of the Committee on Agriculture. 95th Congress, 1st session on H.R.8150, 16 Sep. 1977a.

———. Senate. Hearings before the Subcommittee on Environment, Soil Conservation, and Forestry of the Committee on Agriculture, Nutrition and Forestry. 95th Congress, 1st session on S.1280 and S.1616, 2 and 4 Aug. 1977b.

U.S. Department of Agriculture. *Annual Crop Summary.* ESCS, selected issues 1973–78.

Wischmeier, W. H. "Use and Misuse of the Universal Soil Loss Equation." *J. Soil and Water Conserv.* 31 (1976):5–9.

Wismer, David A. *Optimization Methods for Large-Scale Systems . . . With Applications.* New York: McGraw-Hill Book Co., 1971.

A Conceptual Framework for the Empirical Analysis of Peasants

Carmen Diana Deere and Alain de Janvry

To assist in the design and analysis of the many empirical studies currently conducted on peasants and their changing status in third world countries, a conceptual framework is presented and illustrated with data from Cajamarca in Peru. The framework identifies the key variables to be measured and processes to be analyzed at three levels: the organization of the peasant household in terms of production, circulation, and reproduction; the mechanisms of surplus extraction; and the class position and differentiation of groups of peasants within particular social formations.

Key words: peasants, Peru, social relations.

In recent years the economic and political significance of peasantries in the third world has received increased attention. The active role of peasants in postcolonial struggles has drawn attention to their political importance in the transformation of many third world societies. The economic importance of peasants has been highlighted by the dimensions of the food crises of the 1970s and by the recognition that they are often cheap food suppliers and a source of cheap labor for agriculture and industrial development. The consequence has been an explosion of both research and programs oriented to the peasant question: research to observe, describe, and understand the economic and political logic of peasants, as well as their changing position and functions in broader society, and programs to increase the productivity of labor in peasant agriculture and to promote political stability in spite of massive poverty. Thus, a large number of empirical studies have been conducted, frequently in the context of the search for new technologies adequate for peasant farming or the design of rural and community development projects.

The research effort has demystified many of the concepts that dominated much of the early work on peasants, such as cultural traditionalism, economic backwardness, and the autarky of subsistence production. Yet, the absence of an adequate conceptual framework for the study of the peasantry too often has prevented these studies from isolating the key variables required for analysis and from organizing the empirical information in terms of the central processes that characterize peasant households and the forms of their insertion into the wider economy. For the economic analysis of the organization of peasant households, reliance typically has been placed on either the Chayanovian theory of utility and demographic differentiation (Chayanov, Archetti) or on strict neoclassical principles derived from the theory of the capitalist firm (the formalists in anthropology—Tax, Nash, Leclair; the new household economics—Becker, Benito). For the analysis of the insertion of the peasantry into the broader society, either a phenomenologist and cultural vision of partiality has been used (Kroeber, Redfield) or the conceptualization of specific noncapitalist peasant modes of production has been relied upon (Servolin; Vergopoulos 1971, 1978).

In this paper it is argued that the analysis of peasantries must be based on the specification of the relations of production in which peasants participate. We reject both Marxist and non-Marxist attempts to define a peasant mode of production or peasantry as a specific sociocultural or economic type and focus on the mechanisms of surplus extraction which describe the relations of production between direct producers and appropriators in class societies.

We take the situation where the capitalist mode of production is dominant in the econ-

---

Carmen Diana Deere is assistant professor of economics at the University of Massachusetts; Alain de Janvry is associate professor of agriculture and resource economics at the University of California, Berkeley.

Giannini Foundation Paper No. 535.

omy at large and focus our inquiry on the forms of integration of peasants into the social formation. This framework highlights the conditions under which peasant households become integrated into markets as suppliers of products or of wage labor. We argue that the integration of the peasantry into the labor market, as suppliers of wage labor to capitalist units of production or as buyers of wage labor in the process of capitalization, most closely characterizes the process of class formation among direct producers and, hence, their incorporation into the dominant capitalist mode of production.

The conceptual framework developed here attempts to account for the variation in the material conditions of peasants as well as for the dynamics of their transformation by interrelating three levels of analysis: (*a*) the organization of the peasant household, (*b*) the mechanisms of surplus extraction, and (*c*) the class position of different groups of peasants within particular social formations. The framework is illustrated with data describing the Cajamarcan peasantry of the northern Peruvian sierra.

Organization of the Peasant Household

In order to highlight the interrelated social processes that characterize the peasant household, Marx's categories of production, circulation, reproduction, and differentiation are drawn upon. What distinguishes the peasant household from other domestic units (such as the household in advanced capitalism) is that the household is both a unit of direct production and a unit of reproduction of familial labor power on both a daily and generational basis.

At a given moment in time, the stock of family labor in relation to the household's access to the means of production is reflected in the particular division of labor by sex and age embodied in the household labor process. Household labor power is used in the home production process or sold as wage labor on the labor market where it participates in what is termed as the wage labor production process. A continuous spectrum of combinations between the two pure extreme types of households—purely agriculturalist and purely proletarian—can be identified.[1]

Household labor dedicated to home production generates a gross product which is either retained as a use value by the household for home consumption or sold on the market as a commodity (the circulation process). Here, again, a continuous spectrum between pure subsistence household production with no marketable surplus and the pure commercial farm that is exclusively producing for the market can be identified.

The sale of commodities and the wages received from the proletarian labor process constitute the gross monetary income. This income, after deduction of the various monetary costs involved in production, generates a net income which permits the purchase of means of consumption for reproduction of the household and means of work for replacement and net investment.

Means of consumption and means of work thus derived from both home production and purchase sustain the reproduction of the household as both a consumption and a production unit (Meillassoux). Reproduction includes both daily maintenance to restore the capacity to work and generational reproductive activities reflected in the size, age, and sex composition of the household.[2] The scale of this reproduction, in turn, determines the pattern of social differentiation and the consequent changing class position and composition of peasants.

The four key processes identified characterize the organization of the peasant household—home production process, wage labor production process, circulation process, and reproduction-differentiation process. They are schematized in figure 1. In the left-hand column,the stocks of means of production at a particular point in time are identified. They include raw materials (land and water), means of work (seeds, trees, animals, tools and implements, fertilizers, and fuels), and family labor (number, sex, and age of members). In the right-hand column the monetary variables that characterize the circulation process on both the supply and demand sides are presented: gross cash income from sales,

[1] For the sake of simplicity, we abstract from the myriad of home production processes (such as artisan production, small merchant trade, etc.) which might be a complement or substitute for the agricultural/wage labor duality.

[2] While production is ultimately the determinant of reproduction in a relative sense in that the level of the outcome of productive activities determines the household's consumption possibilities and, hence, the level of living at which family labor power can be reproduced (nutritional level, fertility, etc.), the peasant household's reproductive strategy also conditions the productive activities in which it may engage (Mamdani, Folbre).

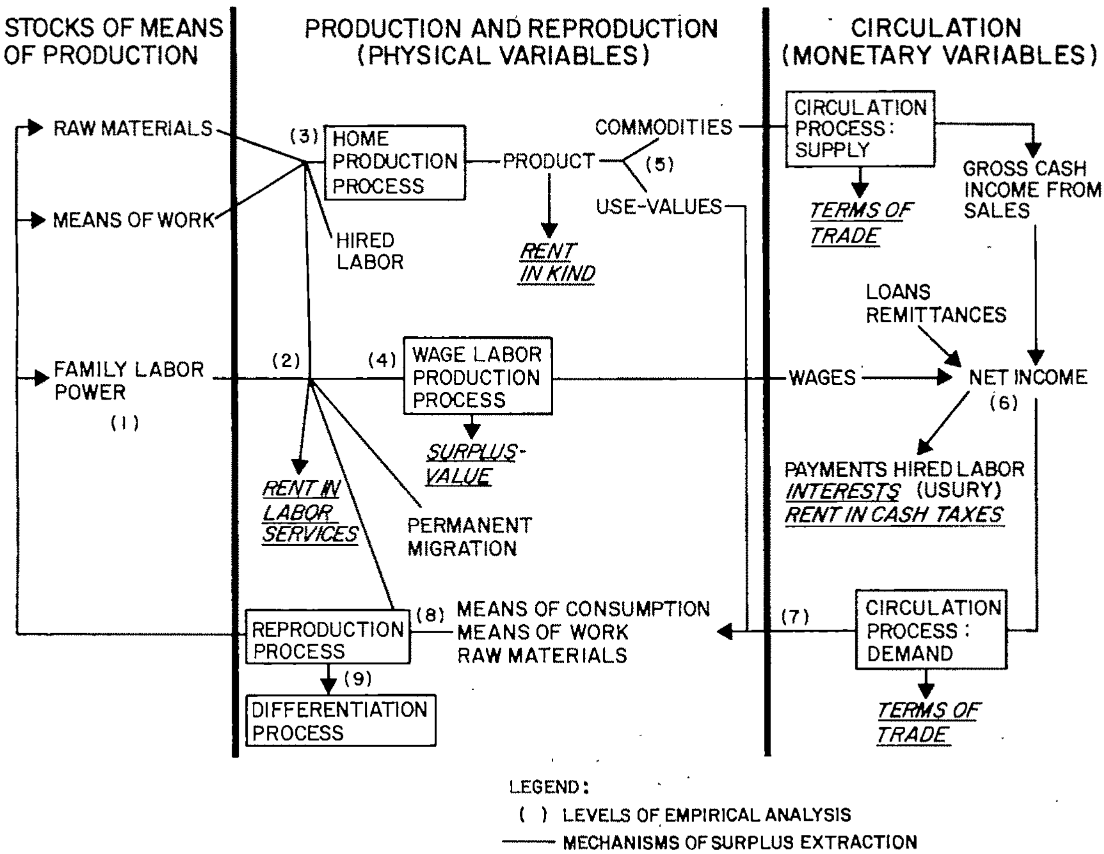


Figure 1. Organization of the peasant household

wages, net income formation, and purchase of means of consumption and work. The center column highlights the two fundamental processes of production (home and wage labor) and reproduction (of the consumption unit and of the means of work). These two key processes are partially mediated through circulation in terms of the formation and disposition of net income but also directly reflect the social relations of production.

From figure 1, nine key sets of variables can be identified for the empirical analysis of the peasant household. These variables correspond to the different nexuses which indicate that either a process of choice and decision making is taking place or that an accounting identity can be established. They are (1) the stocks of means of production at time t; (2) division of labor by sex and age in the household process; (3) choice of activities (products and technologies) and allocation of resources in the home production process; (4) choice of activities and job search in the wage labor production process; (5) disposition of the product between sale (marketing) and retention for home use; (6) the formation of net income (sources of income); (7) effective demand—disposition of net income; (8) reproduction of the consumption unit (family labor) and of the means of work, acquisition of raw materials; and (9) the level of stocks of means of production at time $t + 1$ which provide the basis for the analysis of social differentiation.

Organization of Peasant Households in Cajamarca

The Cajamarcan peasantry is a *mestizo*, Spanish-speaking peasantry resident in the most populous Peruvian Sierra Department. As table 1 illustrates, access to the means of production among the peasantry is highly unequal.[3] Some 72% of the total number of rural

[3] The data presented herein were derived from two sample surveys representative of the distribution of land ownership in 1972. The 1973 Cajamarca Income Survey was carried out by the Socio-Economic Study Group of the Cajamarca-La Libertad Project under the direction of Ing. Efrain Franco. The survey included 1,500 observations on peasant households in 13 districts of the provinces of Cajamarca and Cajabamba. The data presented herein is restricted to 1,050 households in the province of

Table 1. Stocks of Means of Production According to Social Strata

Social Strata (Total Land Used by Each Household)	Distribution of Households	Average Amount of Land Owned[a]	Frequency of Oxen Ownership	Average Number of Oxen	Mean Value of Means of work[b]	Mean Value of Total Assets[c]	Average Number of Persons in Household
	(%)	(hectares)	(%)		(US $)	(US $)	
Landless peasants (0–0.25 hectares) $n = 140$[d]	13.3	0.16	15	0.2	50.33	172.69	5.6
Smallholders (0.26–3.50 hectares) $n = 619$	59.0	1.33	36	0.7	127.86	255.72	5.6
Middle peasants (3.51–11.0 hectares) $n = 177$	16.9	5.83	57	1.2	261.77	520.12	6.1
Rich peasants (11.01–30.0 hectares) $n = 81$	7.7	15.86	82	2.1	461.02	1,146.60	6.5
Farmers (30–100 hectares) $n = 33$	3.1	47.81	79	2.3	545.28	2,414.19	7.9
Total $n = 1,050$	100	4.52	41	0.9	178.90	425.79	5.9

Source: Derived from the 1973 Cajamarca Income Survey for the province of Cajamarca.
[a] The correlation coefficient between land held in property and total land used is .9822.
[b] The mean value of the means of work includes the present value of tools and equipment and the market value of work animals (donkeys, mules, horses, and oxen). Valuation is in 1973 dollars.
[c] The mean value of total assets includes the present value of buildings and equipment and land in pasture as well as the total stock of animals.
[d] n indicates the number of observations.

households have access to less than 3.5 hectares of land each, the minimum—given the ecological and technical conditions of production—that is required for a peasant family to be able to produce its full subsistence requirements. Middle and rich peasant households with sufficient land to be viable agricultural units constitute only 25% of the total number of rural households; their landholdings average 6 and 16 hectares, respectively. The commercial enterprises of the farmers make up only 3% of the total number of units and, when added to the large landholdings in the area (over 100 hectares), control more than 50% of the total land surface.

The highly unequal pattern of access to land is also reflected in the unequal distribution of other resources. The majority of peasants do not own oxen, the principal draft animal in the area. The average middle peasant household owns one ox, whereas only rich peasants and farmers own an average of two oxen, the number required for plowing. The unequal ownership of draft animals is reflected in the data on the average value of the means of work and in the value of total assets of the different social strata. Finally, there is a positive relationship between the household's access to resources and the average household size.

Household composition and structure interact with a given stock of the means of work to determine not only the division of labor by sex and age within the peasant household but the number and composition of activities in which a given household may engage. The specific division of labor by sex and age will vary over the family life cycle and according to the range of activities which the household may pursue (given their access to the means of production) as well as with the social valuation of male and female labor. Tables 2 and 3 give a static picture of the division of labor by sex in productive activities and the differing rates of household participation by social strata in a series of income-earning activities.

Table 2 presents the data on the principal family member that is charged with the re-

---

Cajamarca. The 1973 survey provided the population for a follow-up survey of 105 households; the 1976 Peasant Family Survey, focusing on the familial division of labor by sex, was carried out by the authors.

Table 2. Division of Labor by Sex and Age: Familial Activities According to the Principal Family Member Responsible for the Activity, All Households

Processes and Activities	Mother's Principal Responsibility	Father's Principal Responsibility	Children's Principal Responsibility	All Family Members' Responsibility[a]	Total
	(%)				
Home production process					
Agricultural work $N = 102$	5.7	64.5	7.6	22.2	100
Animal care $N = 92$	61.9	4.4	22.9	10.8	100
Agricultural processing $N = 105$	93.4	0	1.9	4.7	100
Artisan production $N = 101$	66.7	18.4	11.5	3.4	100
Wage labor production process and commerce					
Proletarian wage work $N = 23$	13.0	43.5	30.4	13.1	100
Semiproletarian wage work $N = 51$	9.8	47.1	17.7	25.4	100
Commerce $N = 28$	85.7	10.7	0	3.6	100
Reproduction process					
Cooking, $N = 105$	93.4	0	2.8	3.8	100
Washing clothes, $N = 105$	93.3	0	4.8	1.9	100
Hauling water, $N = 105$	78.3	1.8	10.3	9.6	100
Collecting wood, $N = 105$	58.1	16.2	9.5	16.2	100

Source: 1976 Peasant Family Survey.

[a] Includes cases where mother and father share responsibility for the activity, where other family members carry out the activity, and where parents and children carry out the activity with equal responsibility.

sponsibility for directing and carrying out the series of household activities aggregated over all social strata. Mothers, principally assisted by daughters, carry out the myriad of activities which are required to reproduce familial labor power on a daily basis. But women also play an active role in home production activities. In the majority of households, women are charged with animal care in addition to agricultural processing and artisan production. Men, in contrast, are the principal agriculturalists. In the majority of households that participate in the labor market, fathers and/or sons are the wage workers. However, commerce is an off-the-farm activity that is generally in the female domain.

As table 3 indicates, there is significant variation in the composition of income-generating activities in which different strata of the peasantry engage. Whereas the overwhelming majority of peasant households participate in direct agricultural production or in animal-raising activities, the salient feature of the table is the different degree of participation in the labor market by social strata. Whereas the majority of landless and smallholder households have at least one labor market participant, only one-third of the upper strata of

Table 3. Choice of Income-Generating Activities: Percentage of Households Participating in the Activity by Social Strata

Social Strata	Agricultural Production	Agricultural Processing	Animal Activities	Rental of Resources	Artisan Production	Wage Labor	Commerce	Migrant Remittances
	(%)							
Landless peasants	95.7	1.4	70.0	4.3	31.4	71.4	8.6	13.6
Smallholders	99.0	1.0	79.5	8.4	28.6	55.7	8.6	13.9
Middle peasants	99.4	1.7	85.9	13.0	32.8	41.8	9.6	6.2
Rich peasants	97.5	1.2	95.1	21.0	33.3	34.6	8.6	6.2
Farmers	93.9	6.1	90.9	18.2	36.4	30.3	6.1	6.1
Total	98.4	1.3	80.9	9.9	30.4	53.1	8.7	11.8

Source: Derived from the 1973 Cajamarca Income Survey for the province of Cajamarca.

peasant households engage in the sale of wage labor. The differing access to the means of production is also reflected in the rental of productive resources and in animal-raising activities.

While the majority of peasant households engage in agricultural production, there are significant differences by social strata in the purpose of production (use values versus commodities) and in the magnitude of the activity in terms of the composition of net household income. As table 4 illustrates, an insignificant portion of the agricultural production of landless peasants is sold on the market. Even among smallholders and middle peasants, less than one-third of the total imputed value of agricultural production is sold on the market. Only the rich peasants appear as principally agricultural commodity producers. The farmers are primarily commercial dairy producers. For all strata of the peasantry, cash income from the sale of animal products is relatively more important than that from agricultural production.

While the bulk of agricultural production of the poorer strata of the peasantry is dedicated to use value production, the Cajamarcan peasantry certainly cannot be characterized as "subsistence" producers divorced from the wider economy. Over 80% of the total gross income of the landless and smallholder strata is in the form of monetary income generated by their participation in the product and labor markets. Only the middle peasants exhibit any important degree of "self-sufficiency," although only one-third of their total gross income is derived from home production activities. The data indicate the importance of the integration of the peasantry into capitalist commodity relationships.

Table 5 illustrates that the majority of the peasantry relies on nonfarm sources of income to reproduce their livelihood. Only the middle strata of the peasantry and the commercial farms of the rich peasants and farmers rely on farm activities for a majority of the net mean annual income. The importance of wage income for the landless and smallholder strata is evident and correlates with the high degree of labor market participation of these strata. The data support the proposition that access to the means of production is a key to determining the form of integration of the peasantry to the wider economy: the majority of peasant households with insufficient access to land are increasingly integrated as proletarians, whereas only among the upper strata of the peasantry with their greater control over the means of production is commercial farming a viable activity.

There are important differences in the levels of income generated by different strata of the peasantry. The estimated median net income by social strata is presented in the last column of table 5. The greatest disparity in income levels characterizes the rich peasants and the farmers at one pole and the landless peasants and smallholders at the other pole. The gross median income of the farmers is 22% greater than that of the rich peasant strata, 99% greater than that of the middle peasants, 158% greater than that of the smallholders, and 116% greater than that of the landless peasants.

In 1973 the median net income was on the order of U.S. $156. If the legally defined minimum wage is taken as an indicator of the "moral and historical" minimum subsistence requirement of a worker, the magnitude of rural poverty becomes clearly apparent. In

Table 4. Disposition of the Product: Monetary Income as Percentage of Gross Income by Social Strata

Social Strata	Agricultural Production	Agricultural Processing	Animal Production	Subtotal: All farm Activities	Artisan Production	Total: All Sources of Income
			(%)			
Landless peasants	10.3	98.3	40.6	36.4	84.8	84.8
Smallholders	26.3	87.8	62.9	41.3	72.9	81.7
Middle peasants	29.4	97.0	61.1	43.8	66.5	67.2
Rich peasants	51.1	100.0	130.8[a]	75.8	54.4	81.0
Farmers	27.1	94.3	97.5	73.6	1.7	75.3
Total	35.5	92.0	85.1	59.9	72.1	78.6

Source: Derived from the 1973 Cajamarca Income Survey for the province of Cajamarca.

[a] Monetary income exceeds gross income from animal production (calculated as the value of change in animal inventories plus gross income from animal products) in this case indicating disinvestment in animal stock.

Table 5. Sources of Household Income: Composition of Net Income by Source and Social Strata

Social Strata	Agricultural Production	Agricultural Processing	Animal Production	Rental	Subtotal All Farm Activities	Artisan Production	Wage Labor	Commerce	Remittance	Median Total Net Income
	(%)									(US $)[a]
Landless peasants	1.0	0.1	18.8	0.4	20.3	9.2	55.5	10.3	4.7	165
Smallholders	10.0	0.2	10.0	3.4	24.0	7.1	48.6	12.5	7.5	138
Middle peasants	19.6	0.1	27.0	8.7	55.4	4.1	23.5	10.4	6.6	179
Rich peasants	42.0	0.2	24.4	15.4	82.0	2.1	11.4	3.6	0.9	292
Farmers	26.1	0.1	62.1	1.3	89.6	0.7	5.7	3.3	0.7	356
Total	17.6	0.2	23.6	5.4	46.7	5.2	33.8	9.2	5.0	156

Source: Derived from the 1973 Cajamarca Income Survey for the province of Cajamarca.
[a] Based on 1973 dollars.

1973 the minimum legal daily wage in rural agricultural employment in the district of Cajamarca was U.S. $1.00. A full-time proletarian working 250 days a year would earn approximately 60% more than the annual net median income of the peasantry. Only the rich peasants and farmers earn income above that socially defined minimum required to reproduce the labor force. The other 89% of the peasantry falls below this threshold.

The implications for the development of the home market are clear. While most of the net income of peasant households is generated in monetary form, the low absolute income level restricts the magnitude of effective demand. For the overwhelming majority of the peasantry, net income is destined for the purchase of means of consumption to reproduce their level of living. Aggregated over all strata of the peasantry, the composition of consumption expenditures is dominated by the expenditure on processed foodstuffs (cooking oils, sugar, and flour) followed by expenditures on fuel (kerosene, candles, matches, and wood) and clothing and then on education and health and, finally, on housing and household equipment. Only among the rich peasants and farmers is investment in new means of production significant, primarily in increasing the size of animal stocks.

The level of outcome of the production and circulation processes in which different strata of the peasantry engage determines both the level of consumption possible to reproduce familial labor power as well as the family's access to means of work and raw materials in the next productive period. This, in turn, is the basis for social differentiation to which we will return shortly.

Patterns of Surplus Extraction

Appropriation of part of the product of peasants by other social groups has been identified as a defining characteristic of peasantries by Marxists and non-Marxists alike (Wolf). Within Marxist discourse, the social relations of production in which peasants participate are, in fact, defined by the manner in which the surplus labor time of direct producers is appropriated by a nonproducing class. From an empirical standpoint, we must first identify the mechanisms through which surplus extraction occurs in order to analyze the relations of production into which the peasants enter. In this manner we can then single out different groups of peasants. The model of the organization of the peasant household presented above can be used for this purpose. In figure 1, seven mechanisms of surplus extraction are identified: three operate via rents that result from private appropriation of the land (rents in labor services, kind, and cash), three operate via the markets (for labor, products, and money), and one through the state (taxes).

(*a*) Rent in labor services (*corvée*): family labor is forced to provide unpaid labor services on the landlord's estate in order for the peasant household to acquire the usufruct right to land from which to produce its subsistence consumption. This type of rent characterizes semifeudal or servile relations of production.

(*b*) Rent in kind (sharecropping): the direct producer gives to the owner of the land a predetermined amount or a fixed share of the product in exchange for access to the land and occasionally to some means of work. Rent in kind is a direct subtraction from the gross product before the residual is divided into use values and commodities. Rent in kind also may characterize semifeudal relations of production or represent a form of land acquisition and surplus extraction among different groups of peasants.

(*c*) Extraction of surplus value: in capitalist relations of production, labor power is sold for a wage to those who own the means of produc-

tion. In the production process, labor generates a product, the value of which is greater than the costs of replacement of the physical capital resources and the wage labor used in production. A profit is thus generated which results from the "exploitation" of labor power in the production process. Semiproletarian peasant labor can, however, be further exploited indirectly because the wage level can fall below subsistence needs (for maintenance and reproduction) as part of these needs are provided by the family in the home production process. Cheap peasant labor, extracted through "functional dualism" (de Janvry and Garramon), is thus a major source of exploitation of peasantries under capitalism in the third world.

(*d*) Extraction via the terms of trade: unfavorable prices for the commodities sold relative to the commodities purchased (means of consumption and means of work) is the dominant form of surplus extraction from independent peasant producers. Once capitalist commodity relations have developed, low agricultural product prices may result from a variety of causes including competition with capitalist agriculture, international transmission of prices, cheap food policies, and monopolistic merchants capturing high profit margins.

(*e*) Usury: the instability of peasant agricultural production often results in peasant indebtedness to local moneylenders (merchants, landlords, and rich peasants) who charge usurious interest rates. The money market thus becomes an important source of surplus transfer.

(*f*) Rent in cash: with full development of a money economy, the rental of land is increasingly paid in cash. The peasant farm thus needs to be increasingly commodity-oriented and specialized. In contrast to the other forms of rents, production and price risks are shifted completely from the landowner to the peasant producers.

(*g*) Taxes: taxation assumes different forms —head taxes, land taxes, market taxes, export taxes, and income taxes—with differential impact upon the peasant economy. All represent important sources of fiscal revenues for the state and usually a transfer of surplus from the peasantry to other classes in the social formation.

Once the mechanisms of surplus extraction have been identified, the controversy over the economic logic of peasant households becomes essentially trivial.[4] Simple reproduction of the peasant household (its inability to accumulate) is not based on a given behavioral determination (that peasants prefer to produce only their necessary subsistence requirements) but, rather, must be located in the relations of production that presume surplus extraction. What is key is the dominated class position of peasants within different social formations.

The empirical analysis of the mechanisms of surplus extraction in a given social formation necessarily requires historical analysis because distinct relations of production are maintained by a complex interaction of political, ideological, as well as economic elements. To illustrate, in the Cajamarca area the hacienda system was the dominant rural institution well into the 1950s. Peasants gained access to land on the hacienda through the provision of rent in labor services, in kind, and in cash. An important characteristic of semifeudal or servile relations of production in this area was that the various mechanisms of surplus extraction through rent were superposed, and landlord-peasant arrangements exhibited a combination of forms. Nevertheless, three groups of peasants can be characterized according to their main form of rent payment (Deere).

The *colonos* were the peasants who paid the predominant form of their rent in labor services; the most common arrangement called for an approximately equal division of time between labor services required by the landlord and the familial labor time left free for the family's own subsistence production. The group of peasants called *partidarios* or *medieros* were generally sharecroppers; the

[4] Few controversies have generated less insight than that concerning the economic logic of peasants: do peasants engage in the calculus of economic maximization in the allocation of scarce resources among alternative ends or are there specific economic rules that characterize peasant economic behavior that, in particular, negate expanded reproduction? In anthropology the conflict has assumed confrontation proportions between formalists (Firth, Tax, Nash, Leclair) who assume the former position and substantivists (Polanyi, Dalton, Sahlins) who assume the latter. Agricultural economists, with their neoclassical heritage, have nearly all stood on the side of the formalists (Schultz, Hopper, Lipton).

For empirical purposes, specification of the peasant's economic objective function is indeed important, but the characteristics of the particular social formation within which peasants are inserted must be specified first. Once this specification has been made, the controversy becomes essentially trivial. Each mode of production clearly has its own ideology and economic rules which, when reflected at the level of the social formation, condition economic behavior and the economic possibilities for peasants to reproduce themselves as direct producers.

landlord provided the land and the seed and sometimes the oxen for plowing, while the peasant family provided the labor. The crop was usually divided into equal shares. The *arrendires* on the hacienda were the peasants who paid their rent in cash; this arrangement was most common for the rental of grazing land. Notwithstanding the payment of rent in kind or in cash, these latter two groups of peasants also provided labor services to the landlord which ranged from two weeks to three months of labor services per year, depending on the personalized landlord-peasant relationship as well as the labor requirements of the landlord.

Other mechanisms of surplus extraction on the hacienda focused on the landlord's control over any marketable surplus that the peasants may produce after the payment of rent. On many haciendas, the resident peasants were required to sell any of their surplus production directly to the landlord; at other times, certain specified quantities of produce or animals were to be sold to the landlord at an established price. On many of the larger haciendas, the landlord also operated a country store where peasant families were required to purchase their nonproduced necessities. These commodities were often provided on credit for payment at harvest time at prices set by the landlord.

With the dissolution of the traditional hacienda system in the 1950s and 1960s, the majority of peasants were expelled from hacienda lands and became independent peasant producers—owners of their own plots of land acquired from the division and sale of marginal hacienda lands. The haciendas themselves were transformed into large-scale commercial farms using wage labor. With the change in the relations of production, rent was no longer paid directly to the landlord, and the landlord no longer controlled the circulation of commodities. But as the peasantry became increasingly integrated in the product market, they became more dependent on the upper strata of the peasantry and the farmers who now were to serve as both the primary providers of credit and petty monopolists in rural markets. In addition, the rapid integration of the peasantry into the labor market assured that low wages would become a principal source of surplus extraction as the rural areas became the storehouse of surplus labor.

For the rural sector at large, the unfavorable terms of trade between agricultural and manufactured products constitute an important source of surplus transfer. In the 1973 to 1975 period, the terms of trade were deteriorating at a rate of 8.6% per year (Acevedo). While quantitatively the bulk of commercial agricultural suppliers are found among the upper strata of the peasantry and the commercial farms, these sectors are able to face deteriorating terms of trade only due to the plentiful supply of cheap labor available from the poorer strata of the peasantry. The poorer strata are squeezed at both ends: as wage workers, they receive a wage significantly less than the value of what they produce; and, as producers, they are faced with deteriorated prices for the commodities they sell to insure cash needs.

The Class Position of Peasants and Differentiation

Having characterized the organization of the peasant household and the patterns of surplus extraction through which peasants are exploited, we move on now to locate the peasantry as a social category within the broader society of which it is a part. Doing this implies taking sides in the debate opened in Russia at the turn of the century between Bolsheviks and Populists regarding the specification of a unique peasant mode of production. This debate has been reopened actively in recent years as an understanding of the future economic contribution and the political role of peasants requires the conceptualization of their position in the economy and in society (Ennew, Hirst, Tribe).

The debate is more than rhetorical, as it leads to markedly different interpretations of (*a*) the economic logic of peasants and (*b*) the future of the peasantry. For those who argue the existence of a specific peasant (or simple commodity) mode of production, peasant economic behavior is not guided by the motive of accumulation but by the objective of simple reproduction. The usual description highlights the family labor farm as the basic unit of production and private property in land which is distributed on a relatively equalitarian basis among households who form a single class. Wage labor is generally not employed, and the production of commodities has as its ultimate goal only consumption. While Marx developed the concept of petty commodity mode of production as a theoretical abstraction in *Capital*, those who employ the concept as a histor-

ical reality (Servolin; Vergopoulos 1971, 1978; Amin; Gutelman) argue that it is observed as articulated to and dominated by other modes of production to which it is functional, surrendering a surplus. The implication, however, is that this peasant mode does have the wherewithal to reproduce itself over time, resulting from its capacity to resist internal differentiation into social classes because accumulation is presumably not a behavioral objective of peasants.

There are, in our opinion, two objections to the use of the peasant mode of production concept. The first is that the specific form of organization that corresponds to peasant households and the existence of mechanisms of surplus extraction are not sufficient to constitute a peasant mode. As a theoretical category, a mode of production implies the specification of a determinate set of social relations and an ideological-political superstructure that remain here unidentified. The mechanisms of surplus extraction are not immutable but, to the contrary, assume a wide variety of forms that correspond to the particular social formations in which peasants are encompassed.

The second objection concerns the observed economic condition of simple reproduction. Do peasants want simple reproduction, or is it that they cannot overcome simple reproduction due to surplus extraction that cancels accumulation? In our opinion, the fact—simple reproduction—is wrongly given explanatory capacity on a behavioral basis while the essence—surplus extraction—is omitted. Clearly, under feudal and communal modes, the possibilities of accumulation and differentiation are severely reduced by the nonexistence of labor and land markets. However, when these markets prevail (i.e., when both labor and land have become commodities under the capitalist mode), the empirical observation of concentration of the land by some peasants and increasing proletarianization of the many—whenever economic and social conditions permit retention and accumulation of a surplus—is a clear contradiction of the peasant mode concept.

For those who oppose the notion of a specifically peasant or simple commodity mode of production, peasants are conceptualized either as a class within a given mode of production (e.g., serfs under feudalism) or as elements of a class under capitalism (Marx, Lenin, Kautsky, Preobrazhensky). Under feudalism, the peasantry was the essential class of direct producers subject to the appropriation of their surplus labor by a nonproducing class—the lords. Under capitalism, peasants are a transitory and differentiating class in a process of decomposition and absorption by the essential classes—proletariat and bourgeoisie—of the mode of production. In the analysis of a specific social formation characterized by heterogenous relations of production, the patterns of surplus extraction are the most revealing indicators of the elements of class: rent in labor services and kind under feudal or servile relations of production; and appropriation of the surplus through circulation (terms of trade) and labor process (wage) under capitalist relations of production.

As the development of capitalism progresses in agriculture, the feudal and communal modes decompose, releasing their peasantries which become incorporated in the capitalist mode as a highly unstable class of direct producers subject to differentiation based on their access to the means of production and the subsequent sale or purchase of wage labor. Following Lenin's characterization of the "farmer road" to capitalism, a few are able to employ wage labor and thus capitalize their production process, and become increasingly specialized as commodity producers, whereas the majority must increasingly rely on the sale of their labor power as they lose access to the means of production. In figure 1, changes over time in the levels of reproduction of the means of subsistence and work give the economic basis of differentiation.

Among the lower strata of the peasantry, the low income level continually encourages permanent migration from the household of sons and daughters old enough to capture their own opportunity cost on the labor market. In many cases the deteriorating level of income attained from the combination of home production and wage work in the rural areas or from temporary migration requires the whole family to leave for the urban environment where temporary work may be easier to find, notwithstanding high rates of unemployment. In Cajamarca approximately 2.2 households per hundred leave the rural area annually for urban centers. In many cases these households continue sharecropping their meager land parcels with neighbors or family members but, after a while, sell out.

Conceptualization of the peasantry within the capitalist mode of production as oscillating elements of class between proprietor and worker is also revealing of the political posi-

tion of peasants. The upper peasantry, with its petty bourgeois character, is tied economically to the bourgeoisie but ideologically to the mass of peasants. It thus constitutes a buffer class between bourgeoisie and proletariat in the increasingly polarized rural population. In recent years, a number of reforms promoted by the state have attempted to recreate this category for the purpose of political stabilization. Land redistribution, settlement schemes, and efforts at rural development have this significant—if not always explicit—political dimension.

In our analysis, the peasantry as a producer of commodities is thus only a transitory social stratum under capitalism. Transition does not, however, imply a particular pace. Indeed, this transition can last for a long time; and the absolute number of peasants in the third world still may increase for a long time to come under the double force of the demographic explosion and the decomposition of feudal and communal modes that eject their peasantries into the capitalist mode of production. Yet, these peasants differentiate and are reproduced increasingly as wage workers: the majority gradually lose their status of producers of commodities while attempting to maintain that of producer of use values as a necessary complement to wage earnings in insuring household subsistence. This, at least, is what the peasantry of Cajamarca is currently undergoing.

[*Received June 1978; revision accepted March 1979.*]

References

Acevedo, Nelly. "El Sistema de Commercialización en la Economia del Area de Influencia del PPCLL." Mimeographed. Programa de Estudios Socio-Economicos, Proyecto Cajamarca-La Libertad, Cajamarca, 1976.

Amin, S. *Unequal Development.* New York: Monthly Review Press, 1976.

Archetti, E. "Peasant Studies: An Overview." *International Research in Rural Studies: Progress and Prospects*, ed. H. Newby. New York: John Wiley & Sons, 1978.

Becker, Gary. *Human Capital.* New York: National Bureau of Economic Research, 1964.

Benito, Carlos. "Peasants' Response to Modernization Projects in *Minifundia* Economies." *Amer. J. Agr. Econ.* 58(1976):143–51.

Chayanov, A. V. *The Theory of Peasant Economy.* Homewood, Ill.: Richard D. Irwin, 1966.

Dalton, G. "Peasantries in Anthropology and History." *Current Anthropology* 13(1972):385–415.

Deere, Carmen Diana. "Changing Social Relations of Production and Peruvian Peasant Women's Work." *Latin American Perspectives* 4(1977):48–69.

de Janvry, Alain, and Carlos Garramon. "The Dynamics of Rural Poverty in Latin America." *J. Peasant Stud.* 4(1977):206–16.

Ennew, Judith, Paul Hirst, and Keith Tribe. " 'Peasantry' as an Economic Category." *J. Peasant Stud.* 4 (1977):295–322.

Firth, Raymond. *Malay Fishermen: Their Peasant Economy.* London: Kegan Paul, 1946.

Folbre, Nancy. "Population Growth and Capitalist Development in Zongolica, Veracruz." *Latin American Perspectives* 4(1977):41–55.

Gutelman, Michel. *Structures et Réformes Agraires.* Paris: Maspero, 1974.

Hopper, David. "Allocative Efficiency in Traditional Indian Agriculture." *J. Farm Econ.* 47(1955):611–24.

Kautsky, Karl. "The Agrarian Question." *Economy and Society* 5(1976):2–45, selected passages.

Kroeber, A. L. *Anthropology.* New York: Harcourt, Brace, & Co., 1948.

Leclair, E. "Economic Theory and Economic Anthropology." *Economic Anthropology,* ed. E. Leclair and H. Schneider. New York: Holt, Rinehart & Winston, 1968.

Lenin, V. I. *The Development of Capitalism in Russia.* Moscow: Progress Publishers, 1964.

Lipton, M. "The Theory of the Optimizing Peasant." *J. Develop. Stud.* 4(1968):327–51.

Mamdani, M. *The Myth of Population Growth.* New York: Monthly Review Press, 1972.

Marx, Karl. *Capital.* New York: International Publishers, 1974.

Meillassoux, Claude. "From Reproduction to Production." *Econ. and Soc.* 1(1972):93–105.

Nash, Manning. *Primitive and Peasant Economic Systems.* San Francisco: Chandler Publishing Co., 1966.

Preobrazhensky, E. *The New Economics.* Oxford: Clarendon Press, 1965.

Polanyi, K. *The Great Transformation.* Boston: Beacon Press, 1957.

Redfield, R. *Peasant Society and Culture.* Chicago: University of Chicago Press, 1956.

Sahlins, M. *Stone Age Economics.* Chicago: Aldine Publishing Co., 1972.

Schultz, T. W. *Transforming Traditional Agriculture.* New Haven: Yale University Press, 1964.

Servolin, Claude. "L'Absorption de L'Agriculture dans le Mode de Production Capitaliste." *L'Univers Politique des Paysans,* ed. Cahiers de la Fondation Nationale des Sciences Politiques. Paris: Armand Colin, 1972.

Tax, Sol. *Penny Capitalism: A Guatemalan Indian Community.* Washington, D.C.: Smithsonian Institute of Social Anthropology, no. 16, 1953.

Vergopoulos, Kostas. "Le Capitalisme Difforme." *La Question Paysanne et Le Capitalisme,* ed. S. Amin and K. Vergopoulos. Paris: Editions Anthropos, 1971.

———. "Capitalism and Peasant Productivity." *J. Peasant Stud.* 5(1978):446–65.

Wolf, Eric. *Peasants.* Englewood Cliffs, N.J.: Prentice-Hall, 1966.

Present and Prehistoric Problems of Natural Resources

Ernest W. Grove

The currently developing crisis in natural resources is put in historical perspective as one stage in the ongoing agricultural-urban revolution. This started after the last ice age, when rising seas covered much land while rising populations needed more. Agriculture was not discovered by hunter-gatherers; it was their last resort when game and wilderness became scarce. The result was conflict and near-slavery for most people. Better conditions came with the fossil-fuel (industrial) revolution, but may prove temporary as the natural resources crunch raises questions not unlike those faced by hunter-gatherers some 10,000 years ago.

Key words: agricultural revolution, energy crisis, natural resources, population pressure.

The Fellows Lecture by M. M. Kelso, probably the best so far, presents the development of a land economist in admirably frank and personal terms. It also presents, clearly and unmistakably, the terrible dilemma that what we have learned to call "modern civilization" has only just begun to face. There is even the implication of a possible Armageddon in the not-too-distant future, although Kelso downplays it by referring only to the "apocalypse" (pp. 814, 819).

As many informed citizens are beginning to realize, there is reason for concern, even alarm, about what might happen in the relatively near future—"near" at least in relation to geological time and the 15-million-year evolution of the human race. In fact, the present-day apocalypse, based on seemingly unchecked population growth, has become almost commonplace in recent years. See, for example, Brown's *The Twenty-Ninth Day,* which refers to the next-to-last time period in a potentially disastrous geometric progression.

The Agricultural Revolution

On the other hand, the explosive changes that took place before, during, and after the initial stages of the agricultural revolution some 10,000 years ago are just beginning to be understood. And we should all of us, including agricultural economists, learn as much as possible about the recent findings of archeologists and anthropologists so that the present-day apocalypse, as articulated by Kelso and others, can be put in its proper historical and prehistorical perspective.

Role of Rising Seas

The main point that needs to be made is that the current, obviously precarious situation is just another stage—not the last—in the ongoing agricultural-urban revolution, which probably had its inception some 20,000 years ago after the peak of the last ice age. Melting ice resulted in rising seas, which eventually covered much of the previously available land surface. So Pleistocene hunter-gatherers were confronted with a gradual but inexorable decline in the area of wilderness land—a formidable problem in natural resource economics, even by present-day standards.

According to Pfeiffer, human population had been increasing gradually for ages, but a land squeeze also began about 20,000 years ago. So much water "was locked up in polar ice caps and glaciers that ocean levels stood 250 to 500 feet lower than they stand today. Hunter-gatherers exploited herds roaming over the continental shelf . . ." (p. 69). As the melting started, shorelines receded at a rate of

Ernest W. Grove is Deputy Director, Producer Associations Division, Agricultural Stabilization and Conservation Service, U.S. Department of Agriculture.

a mile or more per century, and a fifth of the total land surface was probably lost in the end.

Role of Population Growth

As to the increase in population, Cohen devotes his whole book, as its subtitle indicates, to a marshaling of the evidence and arguments for an active rather than a passive role for population growth in human history. In other words, and Malthus to the contrary notwithstanding, population growth generally has been the cause of technological change, not the result. Cohen cites Ester Boserup as the originator of this heretical view, and says "in her analysis of agricultural systems she argues that it is not so much technological progress as population density that determines what type of agriculture will be employed. She argues, in fact, that the relative efficiency of various agricultural technologies is largely a function of population density, and that the various known technologies represent a continuous series of more or less elastic responses to growing population" (p. 13).

Cohen summarizes his own views as follows: "I intend to argue that human population has been growing throughout its history, and that such growth is the cause, rather than simply the result, of much human 'progress' or technological change, particularly in the subsistence sphere. . . . By approximately 11,000 or 12,000 years ago, hunters and gatherers, living on a limited range of preferred foods, had by natural population increase and concomitant territorial expansion fully occupied those portions of the globe which would support their lifestyle with reasonable ease. . . . [Beginning about 8,000 B.C.,] populations throughout the world, already using very nearly the full range of available palatable foods, were forced to adjust to further increases in population by artificially increasing, not those resources which they preferred to eat, but those which responded well to human attention and could be made to produce the greatest number of edible calories per unit of land" (pp. 14–15).

Life and Skills of Hunter-Gatherers

Cohen's arguments following this summary are quite convincing, as are also those of Farb, Harris, and Pfeiffer on the same general subject. Earlier theories of agricultural origins held that agriculture was "discovered" about 10,000 years ago when some exceptionally observant individual noticed seeds sprouting in a refuse heap near camp and drew the appropriate conclusion. But this "Eureka theory" grossly underrates hunter-gatherers. "It assumes that they had exploited wild plants for several million years without learning what happens when seeds are placed in the ground" (Pfeiffer, p. 69). Farb also points out that the few remaining present-day hunter-gatherers are almost the equal of professional botanists in their practical knowledge of the plants they are exploiting. Thus, it must be assumed that the knowledge was there all along, but that domestication made no sense in a normal hunter-gatherer context.

There are two reasons why this is so. First, the diet of hunter-gatherers was superior to that of farmers or city dwellers at almost any stage of development. This hardly requires demonstration, since the human organism evolved for millions of years in a hunter-gatherer context, and developed a need for a variety of proteins, vitamins, minerals, and trace elements that were readily available in that environment. And the second reason is that the hours of work required for a decent lifestyle were much less for hunter-gatherers than for primitive farmers.[1] The lifestyle of present-day hunter-gatherers may have little appeal for "civilized" humankind, but they enjoy more leisure than most of us.

Thus, the shift to agriculture could have been made at any time, but it was not a desirable change for advanced hunter-gatherers to make under normal circumstances. Why, then, did the shift take place at approximately the same time all over the world? The answer is: There were too many hunter-gatherers; they were on the verge of starvation, in some areas at least; and there must have been ever-growing conflict among hunter-gatherer bands—which previously had been part of the "peaceable kingdom."

Disappearance of Megafauna

The disappearance of many species of large game animals (megafauna) during the Late Pleistocene constitutes important supporting

[1] This may not have been true when game animals had become scarce, just before the agricultural revolution. But it was certainly true before that. The life of primitive men and women was not "nasty, brutish, and short."

evidence. The possible reasons for this disappearance have been the subject of some controversy, with older theories holding that the extinctions resulted from drastic changes in climate and resulting disruption of food supplies and reproductive patterns (Martin and Wright). But the latest theory, strongly advanced by Martin (1967) during the last decade, is that the extinctions resulted from "overkill," not "overchill." In other words, man the superpredator destroyed his own primary source of food.

The overkill theory now seems to be gaining general acceptance, not necessarily as the sole cause of extinctions, but certainly as an important contributing factor. Martin's main arguments, in fact, are not likely to be successfully refuted. He points out (*a*) that the large mammals had survived previous advances and retreats of polar ice, (*b*) that megafaunal extinctions occurred at different times in different parts of the world, whereas climatic changes were approximately simultaneous worldwide, and (*c*) that, "when examined on a global basis, in which Africa, North America, Australia, Eurasia, and the islands of the world are considered, the pattern and timing of large-scale extinction correspond to only one event—the arrival of prehistoric hunters" (1967, p. 36).

Megafaunal Extinctions in America

Martin (1973) has even developed a model or hypothesis concerning the discovery of America in which megafaunal extinctions are a key element. "At some time toward the end of the last ice age, big game hunters in Siberia approached the Arctic Circle, moved eastward across the Bering platform into Alaska, and threaded a narrow passage between the stagnant Cordilleran and Laurentian ice sheets" (p. 969). "By analogy with other successful animal invasions, one may assume that the discovery of the New World triggered a human population explosion. The invading hunters attained their highest population density along a front that swept from Canada to the Gulf of Mexico in 350 years, and on to the tip of South America in roughly 1,000 years. . . . The model generates a population sufficiently large to overkill a biomass of Pleistocene large animals averaging 9 metric tons per square kilometer. . . . It requires that, on the front, one person in four destroy one animal unit (450 kilograms) per week, or 26 percent of the biomass of an average section in one year in any one region. Extinction would occur within a decade. There was insufficient time for the fauna to learn defensive behaviors, or for more than a few kill sites to be buried and preserved for the archeologist" (p. 973).

If Martin's model for the New World survives future findings, it means that the first North American "frontier" was not the westward agricultural frontier of the nineteenth century, but rather the southward hunting frontier from about 9,500 to 8,500 B.C. In any case, there can no longer be any doubt about the important role of primitive hunters in the large animal extinctions of the Late Pleistocene. Men always had hunted cooperatively in groups, and it is certain that, during the successive advances and recessions of polar ice, these hunting groups had become extremely efficient.[2] The hunters, however, were not conservationists—just the opposite, in fact. Whole herds could be destroyed to provide only short-term sustenance for a small group of people. One method was encirclement with fire. Another was to stampede the herd over a high cliff, with women providing the coups de grace at the base of the cliff. The conservation of natural resources is an idea that imposes itself on the human mind only as a last resort.

Slow Development of Domestication

Agriculture developed slowly and spasmodically in different parts of the world, and reversion to the hunting life probably occurred whenever possible. For example, the Plains Indians had settled down to agriculture because of a scarcity of accessible game animals long before the Spaniards arrived. But when the horse became available again—it had previously been killed off for food by the Indians' ancestors—there was a prompt and enthusiastic return to the hunting life, with the large and previously too formidable buffalo herds as the target. Because the hunting life is still so ingrained in all of us, it seems quite clear that agriculture could have developed only at a time when the comparative advantages were overwhelmingly in its favor.

Domestication of crops provided more food for more people. But domestication of ani-

[2] The bow and arrow may have been invented when the growing scarcity of game animals had made spears relatively ineffective.

mals, in its early stages, could provide no more than was already there. Why did it occur? According to Cohen, "severe territorial competition among human groups," and their growing commitment to sedentary behavior, made it increasingly difficult to exploit wild herds. Domestication of animals was "primarily a means of subjecting them to the requirements of an exploitative system geared more and more to intense exploitation of spatially limited vegetable resources. . . . The only other alternative for human population, as demand for calories and protein continued to grow, would be to eschew the vegetable resources and follow the herds in the fashion of nomadic pastoralists; but this alternative would be available only to a very few" (p. 60).

Importance of Animal Domestication

Thus, animal domestication may have been more a matter of expediency than of sheer necessity; but it was a very important step nevertheless. In the Old World, domestication occurred before all the suitable species had been killed off; and Harris calls this "the greatest conservation movement of all time" (p. 27). "The domestication of sheep and goats was followed rapidly by that of pigs, cattle, camels, donkeys, and horses" (p. 29). These species are herbivores and ruminants, and they thrive on grass, stubble, leaves, and other plant foods which human beings cannot digest. Thus, they were important additions to the new agricultural system, and provided the basis for additional technological advances.

In the New World, on the other hand, Pleistocene extinctions had resulted in an almost complete absence of such species. And this in turn, according to Harris, set the New World on an entirely different path from that of the Old World, and at a much slower pace. Thus, the inadequate diet of the New World "explains why it was that Columbus 'discovered' America and Powhatan did not 'discover' Europe [and why] Cortes conquered Moctezuma rather than the other way round" (p. 29).[3] Humankind is omnivorous by nature, and the elimination of meat from the diet exacts a high price.

The Ongoing Revolution

To summarize, the principal theme that emerges from the arguments and evidence presented by Pfeiffer, Cohen, Harris, and Farb is that humankind is still involved in a revolution that started some 10,000 years ago when its earliest lifestyle, its original traditions, and its established ethics began to crumble. This revolution got started as a response to the threat of extinction—nothing less could have brought it about. According to Pfeiffer, "slowly rising seas and slowly rising populations represented a kind of pace-setting system or background pressure, broad forces on a world-wide scale that brought about the agricultural revolution" (p. 69). The way of life of hunter-gatherers was failing, and gradually more and more of them fell back on their previously "useless" knowledge of plant and animal domestication. "Never before has the life-style of a species . . . changed so utterly and so swiftly. For some 15 million years, members of the family of man foraged as animals among animals. The pace of events since then has been explosive" (p. 28).

The Consequences

Also according to Pfeiffer, some consequences of the agricultural revolution were: (*a*) People had to stay put, so conflict reached new levels of intensity. (*b*) Resulting from increased population, reduced mobility in turn resulted in further and faster increases. (*c*) People concentrated in larger groups, raising the problem of order and security, both internal and external. (*d*) This led to the creation of elites and "absolute divine authority invested in men on earth" (p. 41), part of the price paid for stability. (*e*) Religion was elaborated and enforced as a back-up for this system. (*f*) Emergence of the state required an absolute ruler, preferably divine, to serve as an intermediary between his people and the gods. (*g*) "People were being domesticated along with their plants and animals" (p. 436). (*h*) In particular, the taming of the human male is a slow process that is still going on. And (*i*) "agriculture confronted [the male] with a kind of technological unemployment, a loss of status and self-esteem" (p. 464), and it is possible (though not proved) that this in turn led to contempt for "women's work" and the downgrading of women. As agricultural economists, we should add one more consequence:

[3] It also explains why ritual cannibalism developed as an important feature of the Aztec religion, whereas religions in the Old World developed eventually in the direction of mercy, reconciliation, and atonement. In his two chapters on "The Cannibal Kingdom" and "The Lamb of Mercy," Harris is quite convincing on this score. He even provides a cost/benefit analysis of state-sponsored cannibalism!

(*j*) the development of agriculture made land valuable, and was thus the beginning of a new kind of trouble.

Elaborating on items (*f*) and (*g*) above, Harris points out that the rise of the state meant slavery for most people. "For the past five or six millennia, nine-tenths of all the people who ever lived did so as peasants or as members of some other servile caste or class. With the rise of the state, ordinary men seeking to use nature's bounty had to get someone else's permission and had to pay for it with taxes, tribute, or extra labor. . . . Under the tutelage of the state, human beings learned for the first time how to bow, grovel, kneel, and kow tow. In many ways the rise of the state was the descent of the world from freedom to slavery" (pp. 69–70).

In other words, the agricultural revolution destroyed hunter-gatherer institutions which were, as far as we can tell, reasonably democratic in nature, even egalitarian. The result was autocracy and slavery, or near slavery, for the masses. It took 8,000 years for a very limited form of democracy to reappear in the Greek city-states, and much longer for democratic institutions to reappear in a few modern nations. This resurgence of democracy may have been associated, in part at least, with the so-called "industrial revolution" of the last 200 years. But this is itself best viewed as just one short phase in the ongoing agricultural-urban revolution. And now an "energy revolution" seems to be on its way, bringing stresses and strains not now anticipated by the general public, but convincingly forecast by the experts (e.g., Hayes). Will the coming struggle over energy plunge us back into a new kind of autocracy? Only time will tell.

The Current Crisis

In any case, we apparently have reached a point now where we must reassess our approach to the basic necessities of life. In addition to the unprecedentedly concurrent problems of unemployment and inflation, there are new problems relating to environmental pollution and the rapid deterioration of natural systems throughout the world, the realization that supplies of fossil fuels are inherently exhaustible, and the further realization that there is a growing scarcity of agricultural land and other natural resources. We seem, in other words, in danger of forgetting the lessons of sustained yields and killing the goose that lays the golden eggs.

The Question of Economic Growth

In view of all these problems, the question inevitably arises as to the desirability of further economic growth. But the question may not be ours to decide, for economic growth already has slowed down substantially. Denison has pointed out and measured the recent adverse effects on output per unit of input of "(1) new requirements to protect the physical environment against pollution; (2) increased requirements to protect the safety and health of employed persons; and (3) a rise in dishonesty and crime" (1978a, p. 21). He concluded that there was a significant impact, reducing potential gains in output per unit of input by from 20% to 25% in recent years. Elsewhere (1978b), Denison discussed the "puzzling drop" in labor productivity, as measured by national income per person employed, and concluded that a continuation of the "new and much lower growth path" would be disastrous (p. 12).

Brown stated that "the global engine of economic growth is clearly losing steam" because of humanity's relationship to the carrying capacity of biological systems and to the dwindling reserves of several key nonrenewable resources such as oil" (pp. 188–9). Hayes has twisted the screw even tighter by (*a*) showing that "energy and the gross national product have grown hand in hand at 3 to 3½ percent a year for almost 40 years," (*b*) demonstrating that the growth in energy from all sources has slowed down considerably in recent years, and then (*c*) reaching "the dismaying conclusion that energy growth will all but stop in another decade" (p. 233). Jensen is similarly pessimistic in discussing "Limits to Growth in World Food Production." And finally, Train sounds the alarm on the natural environment: "I am struck by the fact that the real 'bottom line' is the maintenance of life on this earth. Time is running out on the natural systems of the earth, and particularly on the survival of species" (p. 201).

But what will happen to a growing world population without a growing world economy? Pfeiffer insists that the agricultural-urban revolution is still in its early stages. "Man, the postponer supreme, has postponed the task of limiting his numbers . . . for the better part of 10,000 years, primarily because of a succes-

sion of advances in agriculture. He is beginning to realize that this delaying action must come to an end" (p. 23). Other species were "adapted" to their environment, and so were human beings until 10,000 years ago. At that time, our ancestors started to "cheat" by changing the environment. "It still remains to be seen whether or not they [or we] will get away with it" (p. 434).

Scenarios for the Future

What of the future? Will we get away with it? Human nature is such, even among scientists, and the nineteenth century idea of "progress" is so thoroughly ingrained in all of us, that a "positive" answer seems almost inevitable until the force of circumstance proves otherwise. Or, as Tiger puts it (p. 15), "anticipating optimistic outcomes of undecided situations is as much a part of human nature, of the human biology, as are the shape of the body, the growth of children, and the zest of sexual pleasure." Of the five authors cited who have considered the problem, one is essentially noncommittal, three are optimistic in varying degrees, and one is a pessimist.

Pfeiffer is the least inclined to prediction. He says only that, "whatever the future, man is moving into it faster and faster . . . " (p. 19). And he concludes his study as follows: "The great problem was always, and still is, to break away from patterns of repeated conflict, of insults and face-savings and victories and defeats—and to devise manmade environments as secure and abundant as the best of the old and all-but-vanished natural environments of hunter-gatherer times" (p. 476). Easier said than done.

Farb is unconvincingly optimistic, basing his hopes for the future on the rather nebulous concept of "modernization," which is loosely defined as "technology interacting with biological and social systems" (p. 452). Technology has admittedly failed us in recent years, but Farb feels that it has only gone "temporarily out of balance" (p. 452). On agriculture, Farb's views do not jibe with those of Brown and Jensen. He states that "technology is already in existence for a very high-yield agriculture, for intensive farming of the sea to produce algae and shellfish, for developing varieties of plants with high protein content, and for cultivating major new crops" (p. 461). But he does not recognize the likelihood of energy shortages and higher costs as any handicap to the achievement of such high technology. In short, Farb believes "that modernized humans will invent new techniques to meet new needs, as they always have in the past" (p. 471). Maybe so, maybe not.

Cohen is essentially optimistic, as indeed he has to be if he is to remain consistent with his previous analysis. He used a Boserupian demographic stress model, documented archaeologically for hunter-gatherer groups, to explain the nearly simultaneous emergence of agriculture on a worldwide scale. Population pressures induced technological advance; but the latter was (and is) more of a "holding action" than the great measure of "progress" we have thought it to be. The idea of "progress" stems only from the last century, and the "prospect of altering our food supply might be more constructively faced if we realized that it is the prevailing notion of 'progress' rather than the contemporary 'crisis' that is the historical anomaly. Perhaps it will aid us in our economic transition to realize that human populations once faced the notion of eating oysters and later the prospect of eating wheat with much the same enthusiasm that we now face the prospect of eating seaweed, soy protein, and artificial organic molecules" (pp. 285–6). But is Cohen's model still valid in the present situation? Or do changes in circumstances render it invalid? Only time will tell.

Brown is ostensibly an optimist. But he states the problems so well the reader hardly believes him when proposed solutions are advanced. His optimism seems utterly forced. Noting first that managing current problems "will require an exceptional exercise of political will and human ingenuity" (p. 11), Brown suggests that "The Inevitable Accommodation" (chapter 10) to nature's limits will require a "planetary bargain" to include "three components—reform of the international order, social reform at the national level, and the overall accommodation of human needs and numbers to the earth's resources" (p. 300). A tall order.

Brown states that the ethic of economic growth must give way to the ethic of "accommodation" (p. 323). He thinks that national security is becoming less dependent on military strength and more dependent on the various natural resource systems for which he seeks an "accommodation" (pp. 294–6). But nowhere does he seem to recognize that an aggressive nation might decide, on rational

grounds, to use its military forces to produce its own accommodation—on its own terms. In view of the history of military aggression since the agricultural-urban revolution began, how can Brown seem to so thoroughly discount the likelihood of its continued recurrence?

Harris is the outright pessimist, although he does not seem so gloomy as the "Global 2000 Study," sponsored by the White House Council on Environmental Quality and reported by Jack Anderson. Harris argues that cultures assume their characteristic forms in response to available resources. As the demands of growing populations eventually exceed these resources, cultures undertake increasingly intensive forms of production until the original resources reach the point of depletion. Then, if the culture is to survive, it must create a new technology, and the cycle of production, overpopulation, intensification, and depletion repeats itself.

In other words, Harris takes the demographic stress model, used by Cohen to explain the emergence of agriculture, and applies it in elaborated form to subsequent developments as well, right down to the so-called industrial revolution—which should have been called the fossil-fuel revolution. Living standards for ordinary people dropped sharply with the coming of agriculture and did not begin to rise again until early in the nineteenth century. Gains over the last 150 years, resulting from the increasingly intensive use of fossil fuels, have largely represented "a regaining of standards that were widely enjoyed during prehistoric times" (p. x). And the current energy crisis raises a question: Will these gains ultimately prove to have been only temporary?

"As coal and oil become scarcer, their costs will go up. And since virtually every product and service in industrial society depends on large energetic inputs derived from these sources, inflation will steadily reduce the ability of the average person to pay for the goods and services now regarded as essential for health and well-being. . . . Food production, to take the most critical example, has now become totally dependent on our oil supply. Agricultural traction, lifting, hauling, and transport were captured first. Now we have reached the stage where the conditioning of the soil through chemical fertilizers and the defense of plants through herbicides, pesticides, insecticides, and fungicides have also become totally dependent on an ever-increasing supply of petrochemicals. The so-called "green revolution" is an oil revolution. . . . The bubble-like nature of this mode of production can be seen from the fact that, if the rest of the world were suddenly to adopt the energy ratios characteristic of U.S. agriculture, all known reserves of petroleum would be exhausted in eleven years" (Harris, pp. 188–9).

Harris fears the most probable technological solution to our energy problems—nuclear power. This is already associated with the military, and it would require only a few very large plants for efficiency. Thus, with power concentrated in both senses of the word, there could be the danger of a new "energy despotism," which would be similar to the despotism of early civilizations based on control of water.[4] There is also some evidence that "after a society has made its commitment to a particular technological and ecological strategy for solving the problem of declining efficiency, it may not be possible to do anything about the consequences of an unintelligent choice for a long time to come" (p. 163). We live in critical times.

Conclusion

Continuing inflation in the foreseeable future, caused in considerable part by the natural resources crunch, is likely to result in a stalemate for the "American Dream." Beyond that, if world population is not soon checked, there could be a real checkmate, not just for the "American Dream," but for humankind as a whole.

An upbeat ending to this survey, therefore, does not seem entirely justified. It is true that, in the infinitesimal time of recorded history, humankind has managed to muddle through some very serious scrapes with its humanity still recognizable if not exactly intact. But the scrapes have been outlasted largely through the services of the four horsemen—war, famine, pestilence, and death. With these population checks more unacceptable now than ever before, what, if anything, can be substituted for them? For a time it was thought that nuclear weapons might induce the ulti-

[4] In so-called "hydraulic societies," the ruler controlled irrigation water—and through it everything else. He could also expand his rule through conquest.

mate extinction of the human species. Could it be that, instead, they will be merely the agent for weeding out redundant humanity—like the suicidal frenzy of the lemmings—and bringing the human population down to a sustainable size?

But this is speculation. Two firm conclusions seem justified. First, the pace of change in the affairs of humankind has quickened markedly during the last 10,000 years and gives every evidence of becoming even more rapid in coming years. And second, there is nevertheless a recognizable continuity in human affairs which we ignore at our peril. In the current crisis, it is terribly important that humankind should compromise its internal differences, insurmountable as they now seem, and get on with the job of deciding what can be done—and then doing it. We cannot count on muddling through this one.

On the other hand, if we insist on muddling through, the only hope for humanity as a whole probably rests in the inevitable fact that "hope springs internal" in the human species (Tiger, p. 147). Many, perhaps most, will not survive. But the survivors, be they few or many, will feel vindicated. They always have, and they always will. It may be in this sense only that there is "hope" for the human race.

In the meantime, however, and in any case, present-day analysts of the natural resources situation, including agricultural economists, should bear in mind the traumatic experiences of the last 10,000 years in their interpretations of current data and in their formulation of appropriate policies.

[*Received March 1979; revision accepted May 1979.*]

References

Anderson, Jack. "A Gloomy Preview of the Year 2000." *The Washington Post*, 25 June 1978, p. D7.

Boserup, Ester. *The Conditions of Agricultural Growth*. Chicago: Aldine Publishing Co., 1965.

Brown, Lester R. *The Twenty-Ninth Day: Accommodating Human Needs and Numbers to the Earth's Resources*. New York: W. W. Norton & Co., 1978.

Cohen, Mark Nathan. *The Food Crisis in Prehistory: Overpopulation and the Origins of Agriculture*. New Haven, Conn.: Yale University Press, 1977.

Denison, Edward F. "Effects of Selected Changes in the Institutional and Human Environment Upon Output Per Unit of Input." *Survey of Current Business* No. 1 (1978a), pp. 21–44.

———. "The Puzzling Drop in Productivity." *The Brookings Bulletin* no. 2 (1978b), pp. 10–12.

Farb, Peter. *Humankind*. Boston: Houghton Mifflin Co., 1978.

Harris, Marvin. *Cannibals and Kings: The Origins of Cultures*. New York: Random House, 1977.

Hayes, Earl T. "Energy Resources Available to the United States, 1985–2000." *Science* 203(1979):233–9.

Jensen, Neal F. "Limits to Growth in World Food Production." *Science* 201(1978):317–20.

Kelso, M. M. "Natural Resource Economics: The Upsetting Discipline." *Amer. J. Agr. Econ.* 59(1977):814–23.

Martin, Paul S. "Pleistocene Overkill." *National History* no. 10 (1967), pp. 32–8.

———. "The Discovery of America." *Science* 179(1973):969–74.

Martin, Paul S., and H. E. Wright, Jr., eds. *Pleistocene Extinctions: The Search for a Cause*. New Haven, Conn.: Yale University Press, 1967.

Pfeiffer, John E. *The Emergence of Society: A Prehistory of the Establishment*. New York: McGraw-Hill Book Co., 1977.

Tiger, Lionel. *Optimism: The Biology of Hope*. New York: Simon and Schuster, 1979.

Train, Russell E. "The Environment Today." *Science* 201(1978):320–4.

Product Competition and Consumer Behavior in the Food Industries

D. I. Padberg and R. E. Westgren

Conventional hypotheses regarding product competition and consumer buying behavior are inappropriate for examining these processes in the modern food system. Some new hypotheses about product development, consumer behavior, and their interface are presented. Marketing of new products is not driven by new technology but consists of incremental changes in the existing marketing mix. Adoption of products by consumers is not characterized by analytic consumption behavior, but by risk aversion and preference for incremental changes in the consumption set. Implications for the public interest in these processes are discussed.

Key words: consumer buying behavior, marketing mix, product development, public interest.

Food product competition, particularly with emphasis on product evolution and new product introduction, is of great importance to agricultural economists. A substantial portion of science in the food sector is applied here. Competitive rivalry between major firms occurs at this interface. Structure and behavior of the industries which purchase farm outputs are determined as a result of this process. Dietary patterns and public health, the attitudes of consumers, and the nature of food politics are extensively influenced by these initiatives. Despite the importance of this topic, relatively little attention has been given it. In the instances where agricultural economists have addressed this topic, analysis has been guided by the most primitive hypotheses.

As the public interest in agriculture changes from a focus on the farmer as a disadvantaged interest to include food policy and consumer interests, the attention of agricultural economists must be drawn to these issues. Evidence of increasing public concern with the role of the food industry in consumer welfare is demonstrated by the growing demand for comprehensive national and international food policy and a heightened interest in food safety. (The aspects of the 1977 Farm Bill dealing with human nutrition are a significant example.) These developments will lead to expanded analysis of food product evolution and competition by food scientists and economists. In preparation, this paper will present conventional hypotheses (and explore their implicit roots) and develop some new ones which may be more useful. Examples will be drawn primarily from the food system.

Conventional Hypotheses

A useful beginning may be the identification of hypotheses formed by our experience and thought. Perhaps the most durable of these are the notions within the old quote, "If you build a better mousetrap, people will beat a path to your door." (A similar statement is attributed to Ralph Waldo Emerson. While it is not very useful in economics, it may be judged as quite delightful poetry.) There are two implicit maxims in this quote embraced by economists. The first is that new technology drives product evolution and new product introduction. If the technical advance is significant, product introduction is trivial. A corollary is the maximizing notion that the larger the advance, the greater the welfare increase and faster the uptake of the new technology.

The second maxim is that the other elements of the marketing mix (communications, distribution channels, and pricing) are not integral to the process but merely sales lubricants. Tacitly, the greater advance requires less lubricant. This implies that the measurement

D. I. Padberg is a professor and R. E. Westgren is an assistant professor in the Department of Agricultural Economics, University of Illinois, Urbana.

of the economic value of advertising, for example, evaluates its lubricative capacity. Effects of advertising on the product characteristics purchased by consumers are disregarded. To what extent does advertising provide psychic characteristics (e.g., information, security, status) to the buyer? The naive view of advertising offers no insights into the relationships between product technology and advertising in defining product characteristics.

Another conventional hypothesis is the efficacy of small business held by economists and the public. A great effort is expended to persuade the superiority of small business in new product development. (See, for example, works by Jewkes, Sawers, Stillerman, and Mansfield. Topics are chosen seemingly to avoid consumer products. Most of the innovations are of significance to industrial markets.) The argument centers on the proposition that innovation occurs more frequently in an environment unfettered by bureaucracy. Significantly, this argument is generally used in describing the discovery of a new product or process rather than its introduction to the public. The nexus of this hypothesis with the previous one is the perceived centrality of the technological advance. It has been argued by Galbraith that product competition between firms occurs across all elements of the marketing mix in the introduction of new products, and larger firms have significant competitive advantages in this larger process.

A third conventional postulate that has guided economic analysis is consumer sovereignty in the marketplace. The consumer is characterized by an ability to rationally and completely order consumption bundles. This means the consumer must be able to recognize, evaluate, and rank the characteristics of market goods to achieve maximum satisfaction. This consumer seeks information and makes autonomous and analytical choices. Style or keeping up with the Joneses must be insignificant. This consumer is willing to give sufficient time to this search and comparison process.

Some Hypotheses for Future Research

The following discussion is an effort to extend the accumulation of conventional wisdom into current conditions of consumer affluence, industrial structure, and typical behavior patterns of firms and individuals. Some conventional hypotheses are enhanced, others appear discounted. The following are offered as a tentative outline of significant hypotheses.

(*a*) Product evolution is a broad marketing process spanning changes in product physical characteristics (technology), communications policy, and marketing channels. This process is supported by market research and production methods research. (i) Physical product characteristics and the potential for changing them are often the least significant, least expensive, and least limiting factors in product evolution. (ii) Large organizations may or may not have scale economies in product technology but have advantages in introducing new or differentiated products to consumers—particularly in promotions to the distributive trade and in advertising. (iii) New knowledge about physical product alternatives may contribute little to product evolution because there is no certainty the new product will be introduced. At any point in time there is a stock of product characteristic bundles which does not stimulate the huge investment required for introduction (Skinner). This may be called "redundant technology."

(*b*) Consumers are incrementalists. They want new products similar to familiar goods. They have no scientific or comprehensive standards for evaluating changes in products or judging new products. Big changes are risky and have less value than small changes. (i) Consumers cannot articulate their wants because of the complexity of their choices. They may be able to express the directions of their preferences but no more. Their wants are often only determinate in groups. (ii) Consumers see themselves in a symbiotic relationship with food manufacturers and advertisers. Advertising promotes confidence in purchases by reducing the risk of making choices deemed unsuitable by their reference groups.

(*c*) Public interest in product evolution concerns integrity in communication, sensitivity to collective as well as individual values, waste, conservation, and product safety. (i) Product evolution is an integral part of a society with highly developed scientific capability. Policy should not attempt to minimize or maximize it but try to improve its balance of social and individual effects. (ii) Unregulated product evolution appears sensitive only to individual values. Collective values of conservation, public health, nutrition education, etc., should be encouraged. (iii) Some public interest must be directed toward the enormous

economic power vested in the broad marketing process. The scope of the organizations involved, the vast sums of money spent, the effect on firm growth and decline, and the impacts on consumers are symptoms of this power.

There are three prominent implications to be drawn from the new hypotheses. (*a*) The role of technology-induced product development is muted in the new scenario. (*b*) The role and determinance of consumer behavior are significantly different from conventional analysis. (*c*) The identification and nature of public interest are departures from tradition. These implications merit careful consideration. This paper will not consider these issues empirically but present evidence from other research and recent experience which seems to reflect the new scenario.

Implications for Product Competition

Moving from the concept of a technology-centered process to a model based on extensive redundant technology is a substantive change. Food science offers a vast methodology for altering characteristics of foodstuffs, including taste, form, nutritive content, and preparation. If the cost of introducing one of these changes is large, the firms controlling this technology will be selective in its introduction. What are the criteria for its selection? Little is known about this process in the aggregate. The firm level decision must be based upon (*a*) financial risk of providing capital for production, (*b*) ability to advertise in the matrix of product attributes of competing products, (*c*) possible cannibalization of existing product sales, (*d*) alternative resource use, and (*e*) possible regulatory repercussions.

Attributes of newly introduced products are generally only incrementally different from existing products. The introduction of products closely resembling successful products is seen by firms as less risky than radical changes. Firms are cognizant of the consumer's aversion to radically different goods, and they respond to this preference. Both attempt to minimize risk. This interactive selection process may have more influence on diet and consumption patterns of consumers than the pattern of available technology. Is there a high level of communication integrity linking producers to consumers, thereby making this selection process in the public interest? This position may have validity, but the question is too important to be left to assumption.

The concept of redundant technology needs further elaboration. Is there evidence of a backlog of unused technology for product development and introduction to consumers? Two recent examples are the experiences of Green Giant's boil-in-the-bag technology and the brewing industry's introduction of "light" beers. Both of these technological advances had been explored previously but failed miserably in the market place. With the support of additional market research, new trade promotion and advertising messages were developed. The newly defined marketing mix created successful products. Green Giant and the innovators in the brewing industry showed significant gains in earnings and market share (Bengston, *Business Week*).

The expansion of the definition of product development to include the other elements of the marketing mix represents another departure. This is illustrated by a comprehensive work by Simon which treats advertising as completely independent from product innovation but regards it strictly as a sales lubricant. The process of differentiation and advertising's role in the definition or evolution of product characteristics are not addressed. The confluence of product characteristics and message is evident in consumers' perceptions of products (Silk). To ignore this confluence in assessing the effect of advertising will lead to erroneous conclusions regarding its social significance.

What size of firm is most capable of, and motivated to, innovation? It is indeterminate whether small firms have a competitive advantage in research and development. When innovation is defined as adding to the set of products available to consumers rather than adding to technological inventory, the advantage may be with large, complex firms. Most of the elements of the marketing mix require large investments and have scale economies (Skinner, Marple, Handy and Padberg).

The Role of Consumer Behavior

The consumer role in product evolution is hypothesized differently from tradition. The traditional household provided relatively unsophisticated labor to the assembly line economy and assumed a major role in the processing of food for home consumption. The tasks

of home production required some degree of knowledge and effort in combining purchased inputs. With rising affluence, the complexity of production increased, and the household provided more education, experience, and effort to market labor tasks. Concurrently, consumption activities became relatively less complex. More processing occurred outside the household. Purchased inputs became more diverse. As the value of market labor increased, the value of household time for leisure and consumption activities grew, and the household allocated less time to low valued consumption activities (Schultz).

The assumption of strongly autonomous tastes that related to an economy with limited product choices is inappropriate for the dynamic markets of the second industrial revolution. The plethora of product variations, advertising methods and messages, and distribution alternatives presents the consumer with a confusing set of choices. Choice behavior retreats to habits and impulses with increasing alternatives and decreasing effort allocated to shopping.

The theory of consumer purchasing behavior is considered in its infancy (Woodside, Sheth, Bennett). Cognitive theory suggests the consumer initiates a search process to limit the set of product alternatives from which to make purchase decisions. This search process includes external search in public or social sources and internal search from memory. The complex cognitive processes that assimilate and evaluate this information lead to several manifestations of consumer awareness and behavior. These are discussed at length in Engel, Kollat, and Blackwell; and Sheth. Recent investigations conclude that consumers face an "information overload" in the search process (Jacoby, Speller, Berning; Scammon). The dimensionality of the choice process is too large to construct a complete and ordered set of preferences. The consumers cannot match their perceived product characteristics demand with the product set. This reinforces habituation and limits new product experimentation.

Two inferences can be drawn from the information overload research. Jacoby, Chestnut, and Silberman tested the proposition that as the number of pieces of information on the nutritive content of food products increased and the number of food items shopped for increased, the consumer used fewer nutritive characteristics for decision criteria. Results supported this inference. The second is that the consumer will rely on media advertising as a source of presorted information as the shopping task becomes more complex.

Consumers prefer only incremental changes in new products for two broad behavioral reasons. (*a*) Information overload prohibits the assimilation of all new information. Therefore, it is easiest to appraise the new product in the context of familiar products. (*b*) Consumers seek to minimize the risk associated with new, especially radical, products (Bauer). The consumer takes cues from his environment, particularly from people the consumer associates with or patterns his behavior after, in measuring the appropriateness of product choices. Rothenberg describes this process:

> Why are an individual's tastes deemed worthy of serving as a criterion for his welfare? In an earlier era his tastes could be thought to be a unique representation of what was indissolubly his. The membrane distinguishing the individual from his environment was deemed solid. Social science in the last thirty years has changed this view. Tastes, even personality itself, are now seen made and unmade by the social nexus. The bounding membrane is alarmingly porous. The tastes of an individual—even if we depreciate the effect of advertising—are not nearly so heroically his. They, and he himself, are "only" a relatively stable structure of organized interchanges with a social environment. (p. 281)

The inertia caused by the group nature of consumption pattern determination leads to the introduction of new products with similar characteristics to existing ones. Mass media advertising is implemented to reach a significant portion of the consuming public and convince them of the acceptability of new products and to reinforce the choices for old products.

Consumer reaction to new products often lacks sufficient urgency to elicit analytic behavior from the consumer. Therefore, the novelty factor is often an important aspect of the new product's meaning to the affluent consumer. Scitovsky illustrates several examples of incremental consumer behavior. The Wundt curve suggests that too little variation is boring—but too much is confusing (Scitovsky, p. 35). Again, our communication patterns have considerable redundancy—mixing some new thoughts in usual patterns (so that a friend can finish a sentence when we are half through it). This may seem inefficient, but it would be confusing to get a communica-

tion of all new thought without any familiar comparatives or context (Scitovsky, p. 47).

If educated consumers approached each new product as a matter of sufficient importance to require analysis and preparation, they might be able to react to many of them on the basis of their intrinsic merit. As we retreat into habits, thumb rules, and impulses when confronted with thousands of new products, our reactions take on the patterns usual in reacting to communications and other stimuli. These patterns deal with the new only in small steps and in the context of the old—an incremental process.

Public Interest in Product Competition

Public interest in product evolution and the nature of product competition is unfocused and undeveloped. Two weaknesses in regulatory design are contributory to this. First, monopoly regulation was designed to protect consumers from anticompetitive practices in limited product-line, staple-goods industries. Firm growth and marketing strategies of the second industrial revolution are sufficiently different from turn-of-the-century markets to make most forms of antitrust legislation obsolete. Product competition may have profound (good and undesirable) effects on society, but antitrust does not reach it. Second, past patterns of regulation have been technology-centered, while significant product evolution occurs in other facets of the marketing mix. The Federal Trade Commission alleges that intensive advertising, market channel dominance, and product differentiation are used by breakfast cereal industry leaders to prohibit entry by small firms (Bloom). Bloom argues that the question of efficacy of these industry practices cannot be answered without developing performance criteria for consumer well-being. These practices may be justified by the nature of the product, distribution techniques, and consumer behavior characterizing this market. However, the development of norms for such analysis is tenuous in light of the dynamics of the affluence and socioeconomic changes accompanying the second industrial revolution (Padberg). Economic efficiency norms may be the least important in assessing market performance.

Perhaps questions of advertising integrity and nutrition education have been posed only recently because the public once regarded these issues as concerns of the private domain. Advertising messages and quality were a matter between the consumer and the advertiser. The sovereignty of the buyer was assumed to be sufficient protection from malfeasance. The buyer could vote his preferences by withholding payment and switching to alternatives. Similarly, it was presumed the consumer controlled enough knowledge to make nutritionally optimal purchases.

If these new hypotheses prove valid in explaining consumer and firm behavior, our posture concerning competition policy may change. We may be less inclined to consider advertising categorically wasteful. We may expect less from investments in product technology (which may be redundant). We may define a "public interest" dimension in the whole product evolution process which would require setting public guidelines for directions it might take.

Conclusions

The tendency widely illustrated for researchers to measure technological progress by some quantitative count of technical options and achievements (e.g., patents) appears less than satisfactory. This may identify behavior patterns inappropriately by concentrating on nonlimiting factors in product evolution. Fifty years ago this may have been more appropriate, but present and future usefulness may be secondary.

Arguments regarding advantages of small business in technical achievement are probably irrelevant. Purely technological advances will accrue to the stock of redundant technology and may not result in product advancement in the marketplace. This matter is more related to the marketing event occurring in the other elements of the marketing mix rather than technical product change. The nature of these marketing functions dictate the scale necessary for successful introduction of new products, and the acquired social preference for small organizations and rugged individualism must yield to the pragmatic.

As the roles of advertising and other marketing functions become better understood in the consumption process, consumer behavior research and industrial behavior research will advance. Concurrently, the rationale and justification for regulation of these functions in product competition will emerge. By address-

ing these issues, agricultural economics research will contribute to an efficacious, comprehensive national food policy.

[*Received March 1978; revision accepted April 1979.*]

References

Bauer, R. "Consumer Behavior as Risk Taking." *Dynamic Marketing for a Changing World*, ed. Robert Hancock, pp. 389–98. Chicago: American Marketing Assoc., 1960.

Bengston, R. E. "Green Giant Entry into Frozen Food: The Market Research Story." *Food Marketing and Distribution: Selected Readings*, ed. D. J. McLaughlin and C. A. Mallowe, pp. 225–51. New York: Chain Store Publishing Corp., 1971.

Bloom, P. N. "Potential Contributions of Consumer Research to Antitrust Decision Making." *Advances in Consumer Research V*, ed. H. Keith Hunt, pp. 138–44. Association for Consumer Research, 1977.

Engel, J. F., D. T. Kollat, and R. D. Blackwell. *Consumer Behavior*. New York: Holt, Rinehart, & Winston, 1968.

Handy, C., and D. I. Padberg. "A Model of Competitive Behavior in the Food Industries." *Amer. J. Agr. Econ.* 53(1971):182–90.

Jacoby, J., R. Chestnut, and W. Silberman. "Consumer Use and Comprehension of Nutritional Information." *J. Consumer Res.*, no. 3 (1977), pp. 119–28.

Jacoby, J., D. E. Speller, and C. Kohn Berning. "Brand Choice Behavior as a Function of Information Load: Replication and Extension." *J. Consumer Res.*, no. 2 (1974), pp. 33–42.

Jewkes, J., D. Sawers, and R. Stillerman. *The Sources of Invention*. London:Macmillan & Co., 1969.

Mansfield, E. "Size of Firm, Market Structure and Innovation." *J. Polit. Econ.* 71(1963):556–76.

Marple, G. A. *Grocery Manufacturing in the U.S.* New York: Praeger Publishers, 1968.

"Miller's Fast Growth Upsets the Beer Industry." *Business Week*. 8 Nov. 1976, pp. 58–62.

Padberg, D. I. "Concentration of Powers—Issues and Alternatives." *Increasing Understanding of Public Problems and Policies—1975*. Chicago: Farm Foundation, 1975.

Rothenberg, J. "Consumer's Sovereignty Revisited and the Hospitality of Freedom of Choice." *Amer. Econ. Rev.* 52(1962):269–83.

Scammon, D. "Information Load and Consumers." *J. Consumer Res.*, no. 3 (1977), pp. 148–55.

Schultz, T. "The Increasing Economic Value of Human Time." *Amer. J. Agr. Econ.* 54(1972):843–50.

Scitovsky, T. *The Joyless Economy: An Inquiry into Human Satisfaction and Consumer Dissatisfaction*. New York: Oxford University Press, 1976.

Sheth, J. N. *Models of Buyer Behavior: Conceptual Quantitative, and Empirical*, New York: Harper & Row, Publishers, 1974.

Silk, A. "Preference and Perception Values in New Product Development: An Exposition and Review." *Market Segmentation: Concepts and Applications*, ed. J. F. Engel, H. F. Fiorillo, and M. A. Cayley, pp. 206–24. New York: Holt, Rinehart, & Winston, 1972.

Skinner, R. N. *Launching New Products in Competitive Markets*. New York: John Wiley & Sons, 1972.

Woodside, A. G., J. N. Sheth, and P. D. Bennett. *Consumer and Industrial Buying Behavior*. Amsterdam: North-Holland Publishing Co., 1977.

Estimates of Consumer Loss Due to Monopoly in the U.S. Food-Manufacturing Industries

Russell C. Parker and John M. Connor

Three independent methodological approaches and data sets are used to estimate the consumer loss due to monopoly in the U.S. food-manufacturing industries for 1975. They include estimates (*a*) built up from previously estimated components of consumer loss, (*b*) derived from a regression analysis of the relationship of market structure to industry price-cost margins, and (*c*) derived from regression analysis of the market structure determinants of national brand-private label price differences. All three estimates converge to the $12 to 14 billion range. Virtually all of the consumer loss is attributed to income transfers; 3% to 6% is due to allocative inefficiency.

Key words: consumer loss, food manufacturing, industrial organization, market structure, price performance.

The essence of market power is the ability of a firm to raise the price of its product above the level that would obtain if its market were more competitive. Of the numerous, still tenable theories of oligopoly developed by economists over the last 140 years, all predict higher long-run average prices where seller concentration is high (Weiss), product differentiation is effective (Comanor and Wilson), and/or barriers forestall the entry of new businesses into the market (Bain). The major empirical tests of these hypotheses have generally established statistical relationships between the aforementioned market imperfections and higher profits, an indirect effect of raising prices.

The empirical estimation of the direct losses to consumers due to monopoly prices heretofore has been quite imprecise because of inherent methodological difficulties and lack of appropriate data. The processed-foods industries may be an exception.

Most major industrial groups are composed of industries which produce mixtures of high and low priced products of varying durability and which employ diverse channels of distribution. Food and Kindred Products manufacturing, on the other hand, is characterized by low-unit-priced, high-turnover consumer products sold mainly through grocery stores. To the extent that some of the food industries sell to other industries, such as flour and sugar, customers are mainly other food industries. These characteristics, plus the fact that imports and exports are slight, mean that the Food and Kindred Products industries as a group are largely self-contained and do not present the empirical researcher with the need for complex model specification.

A review of the elements of market structure and performance of the food-manufacturing industries provides ample support for the likelihood of substantial departures from pure competition (Connor, Parker 1976). Not only are market shares, sales concentration, advertising, other product differentiation expenditures, and profits high, but also they have been increasing steadily over the last three decades. The processing and

---

Russell C. Parker is visiting professor in the Department of Agricultural Economics, University of Wisconsin, and an economist with the Bureau of Economics of the Federal Trade Commission. John M. Connor is adjunct assistant professor in the Department of Agricultural Economics, University of Wisconsin, and an agricultural economist with the Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture.

Both authors completed this research while members of the Food Systems Research Group of North Central Research Project NC-117. The research results presented in this paper do not necessarily represent the views of the authors' respective agencies.

The authors wish to acknowledge the invaluable computational assistance of Robert Wills, Pam Bloch, and Mike Murr, and the helpful comments of John J. Siegfried and Michael Gorham. They also received much useful criticism from the discussants and participants of sessions at the AAEA summer meetings in Blacksburg, Virginia, and at the winter meetings of the Allied Social Sciences Association in Chicago, where earlier versions of this paper were presented.

manufacturing of food products occurs in some forty-seven four-digit industries whose competitive structures are quite varied, but in the main they are consumer products industries dominated by companies with high market shares. Increasingly, these leading firms have become consolidated, through merger, into the hands of a few, very large, conglomerate enterprises. Just fifty firms accounted for 64% of food manufacturers' assets in 1978, up from 41% in 1950. Concentration of profits, sales promotion activities, and the holding of leading positions by these fifty firms is substantially higher, ranging upward to 90%.

The weighted average four-firm concentration ratio for all national-market food-processing industries in 1972 was 43%, which is slightly higher than the average of national market industries in the remainder of manufacturing. Adding local market industries (fluid milk, ice cream, animal feeds, bread, and soft drink bottling) and substituting average local for national concentration, the shipments-weighted-average food industry concentration ratio was 52%, indicating a significant degree of oligopoly and potential for competitive problems.[1] Scherer, in his review of the effects of concentration on market performance, concluded that "when the leading four firms control 40 percent or more of the total market, it is fair to assume that oligopoly is beginning to rear its head" (p. 60).

Promotional activities have accounted for a significant increase of the costs of food manufacturers since World War II. Some methods of sales promotion, such as coupons and free samples, provide consumers with price discounts while creating consumer loyalty. Other promotional devices, such as cooperative advertising allowances, special in-store displays, shelf-stocking services, delivery, and information, reduce the costs of retailers or wholesalers. If passed on, these devices would also represent price reductions to consumers. But the bulk of promotional activities currently used for food products (market surveys and test marketing, package design and elaborate packaging materials, point-of-sale advertising, direct mailings, and media advertising) are largely self-cancelling and simply add to distribution costs. IRS data indicate that in 1975 total U.S. advertising expenditures (which include some nonadvertising promotional outlays) by food manufacturers were $4.1 billion;[2] media advertising (TV, radio, magazines, newspapers, and outdoor) of food typically accounts for more than 60% of total food advertising expenditures (Connor). Media advertising of processed foods has risen by an average of 10% per year 1950–75. Because advertising expenses have increased at a much faster rate than sales, the advertising-to-sales ratio of food processors has increased also, from only 1.1% in 1947 to about 2.5% in 1975, with most of the increase accounted for by television advertising.

Persistently high profit rates are another index of monopoly pricing. The profits after taxes, as a percentage of stockholder equity of food manufacturers, have experienced a quarter-century increase of more than 50%. They also have risen relative to profit rates in the rest of manufacturing, itself hardly a model of competition.

The central purpose of this paper is to compute and compare annual "consumer loss" estimates for the U.S. food-manufacturing industries, using three different and independent methodological approaches.[3] These procedures also make use of widely different data bases, two of which have never previously been employed for computing monopoly losses. The estimates display a significant convergence, $12–14 billion for 1975. These large dollar amounts suggest a high payoff for increased public policy attention to competitive problems in the food-manufacturing industries.

Monopoly Loss Theory

Analysis of the welfare effects of monopoly extends back to Dupuit in 1844. Marshall re-

---

[1] Local market industries are more important in food manufacturing because of product perishability or high weight relative to value. There is actually a continuum from completely national to highly local markets, but based on an index of geographic dispersion these five industries are all clearly more dispersed than the other food industries (except for beer).

[2] This figure includes nonfood advertising by the companies but excludes a substantial amount of food advertising by soap and drug companies, other manufacturers, conglomerates, food wholesalers and retailers, and others.

[3] We use the terms "total consumer loss due to monopoly," "monopoly loss due to market power," and similar variants interchangeably. "Monopoly" is intended to encompass not only the 1-firm case but oligopoly as well. The phrase "consumer overcharge," however, is properly used to mean only the income transfer from consumers to the monopolist. Although consumer overcharge excludes the so-called deadweight loss, our estimates indicate that in the food industries most of the total consumer loss consists of consumer overcharge.

fined the concept of consumer surplus, and Lerner extended Marshall's analysis to monopsonists as well as monopolists and to different cost conditions.

Following the framework established by this literature, consumer loss due to monopoly is defined here as the area under the demand curve DD' between the competitive price P_c and the monopoly price P_m (figure 1). To simplify the analysis, we assume that (a) the demand schedule DD' is linear, (b) the monopolist does not price discriminate, and (c) there are constant average costs of production. With increasing marginal costs, both the social-welfare-loss triangle and the monopoly-overcharge-transfer rectangle are enlarged. The total monopoly loss to consumers is represented by the trapezoid P_mP_cCM. The trapezoid has two basic areas: a rectangle P_mP_cRM, which is the sum of overcharges on quantities actually purchased, and the triangle MRC, which is a deadweight or allocative loss incurred by consumers for quantities they would have purchased had the price been the competitive price. Were there a competitive price, consumers would have purchased the additional quantity R to C and would have enjoyed the additional consumer surplus MRC. At the monopoly price P_m, consumers are given price signals that are higher than the opportunity costs for this additional quantity. Thus, consumers are led to consume products they would have regarded as less desirable substitutes were the monopolized food products priced at competitive levels. The triangle MRC is a net loss to society as a whole. No part of it is a transfer as in the case for the overcharge rectangle (P_mP_cRM).

Just how much of the overcharge rectangle P_mP_cRM is an income gain to the monopolist depends on how much higher the monopolist's average costs (X) are compared to the competitive level (P_c). More than 200 years ago, Adam Smith described monopoly as the great enemy of good management; by that he meant that monopolists do not have as strong incentives to minimize their costs of products as do competitive firms. More recently Comanor and Leibenstein have referred to the higher costs of monopolists (rectangle XP_cRE) as "X-inefficiency." These higher costs reflect not only lax management but excessive expenditures on advertising, excess plant capacity, or other costly strategies which protect the monopolist's position from encroachments by competitors. Moreover, monopolistic firms often allow managerial withdrawals in the form of fancy offices, corporate jets, and other inessential perquisites. The monopoly profit rectangle (P_mXEM) that remains after covering the higher costs should correspond to reported before-tax profits in the monopolist's profit and loss statement. However, as suggested by Levinson and Bell, the correspondence is often reduced when firms earning monopoly profits share their gains with their employees through higher wages.[4]

A more rigorous explanation of monopoly loss would relate the area P_mP_cCM to a social welfare loss, defining that as a loss of consumer surplus. No attempt will be made here to reproduce steps and caveats of the traditional proof that the loss of consumer surplus equates to a loss of consumer welfare (see Currie, Murphy, Schmitz). A rigorous calculation of monopoly welfare loss requires assumptions above interpersonal comparisons of consumer utility functions, consideration of the welfare gain of the monopolist, and knowledge of production functions of the products and of their substitutes. However, excluding consideration of the income transfer to monopolists from consumer loss is correct only if income redistribution has no weight in the social welfare function or if there were costless means of offsetting the income distribution effects of market power (Comanor and Wilson).

A full economic articulation of net monopoly welfare loss would adjust the wel-

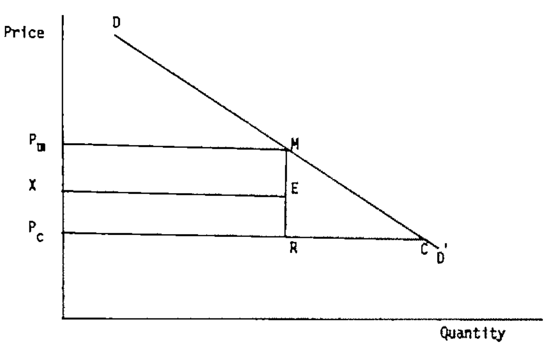


Figure 1. Components of consumer loss due to monopoly

[4] If in a given food industry workers have relatively low incomes and greater equity is a societal goal, then this will reduce further the loss to society that arises from the profit transfer from consumers to the monopolist. However, their incomes must be low relative to both the other claimants on firm monopoly profits (owners and managers) and the consumers of their product to ensure a movement toward greater income equality. Perhaps canned truffles is a product that meets these specifications.

fare loss of consumers (as consumers) by the welfare gain of the monopolist (as consumer) to derive a net welfare loss. Data required for this exercise would include the income distribution of consumers of various products, the income distribution of the various claimants on a firm's rents (owners, managers, government, and possibly workers), and a scale for making interpersonal utility comparisons.

In calculating the following estimates, the increased welfare of the monopolists is ignored, though the omission may not be important if one believes that social equity is served by not increasing material inequality. Food is a basic necessity (a wage good) consumed by all roughly in proportion to dietary needs regardless of income or wealth. On the other hand, the income transfers to monopolies go to a relatively few, higher income individuals whose increased welfare likely would be small in comparison with the welfare loss to all. Indeed, a charter member of the "Chicago School," Richard Posner, has developed a model that assumes that all expected monopoly rents are transformed into gross social costs.

Our estimate of monopoly loss also is overstated by the value received by consumers because of food manufacturers' advertising on information and entertainment media. The value received by consumers from these media is not directly measurable because it is not expressed in a market. Expenditure levels and content are not made in accordance with consumer preference; rather, they are chosen by companies to maximize advertising effectiveness (Doyle). Although advertising expenditures may be efficient in producing private benefits for this purpose, they are likely very inefficient in producing social benefits (Dixit and Norman). Therefore, the authors have made no attempt to adjust their monopoly loss estimates.

Our framework for estimating consumer loss assumes that food product advertising affects only intraindustry preferences for brands and the condition of entry. It ignores all effects on shifting demand between product categories. The authors have substantial reservations regarding this assumption. Comanor and Wilson have found that consumer product demand functions are more responsive to changes in advertising expenditures than changes in relative prices. When changes in interindustry demand schedules occur, additional modifications ought to be made for measuring allocative inefficiency and *X*-inefficiency. The advertising of soft drinks likely has reduced the consumption of milk and fruit juices; the advertising of breakfast cereals probably has caused a decline in the consumption of traditional breakfasts; and the advertising of snack foods and processed foods in all likelihood has caused them to be substituted for fresh products and commodity-type processed foods. Each of these interproduct shifts could well be raising processing costs for food as a sector above minimum necessary levels and may be imposing additional costs on consumers due to health problems aggravated by reduced nutritional levels.[5]

History of Estimation Attempts

There have been very few empirical studies of the loss to consumers due to monopoly, probably because of the general reluctance of economists to deal with questions of equity and technical efficiency. Harberger appears to have been the first to employ the concept of consumer's surplus to quantify the welfare effects of monopolies. Because he considered only the "deadweight" loss triangle (triangle *MRC*) and did not estimate *X*-inefficiency or the profit transfer to monopolists, his estimate was quite small, 0.1% of U.S. national income. Stigler, commenting on Harberger's study, wrote: "If this estimate is correct, economists might serve a more useful purpose if they fought fires or termites instead of monopoly" (p. 34). Subsequent estimates of the "deadweight" loss for the United States generally came to similarly small amounts. One exception is Kamerschen, who, in an innovative paper which considered advertising outlays and employed actual elasticity estimates, arrived at a net welfare loss of 6% of national income. However, his calculations appear to contain a serious arithmetic error (Siegfried and Tiemann). Scherer, however, argues that Harberger's approach subsumes several questionable and restrictive assumptions; more reasonable assumptions would raise the U.S. deadweight loss to a number in the range 0.5%–2.0% of the gross national

[5] Changes in eating habits recommended by the dietary goals (U.S. Congress) have been estimated to enable a family of four to save an annual average of up to $400 on food purchases, roughly eight times our estimates of consumer loss (Peterbin).

product (GNP), with a best-guess estimate of about 1.0% (p. 404).

Scherer estimated total consumer loss for the entire U.S. economy. His estimate included not only allocative or deadweight loss and income transfer but several X-inefficiency components as well. He suggested that the combined total of the X-inefficiency losses was 10% of costs in some industries highly insulated from competition (p. 405). Leibenstein (1978a) cited several industry studies that found excess costs of about 10%, and for all stages of production combined he ventured that he "would be amazed if X-inefficiency wasn't around the 20 percent level for the economy as a whole" (p. 209). With the addition of monopoly profits and deadweight loss, therefore, it is quite possible that the consumer loss could exceed 10% of sales in many industries.

There have been a few estimates of consumer loss in selected industries. Comanor and Wilson applied the results of a profit-market structure regression analysis to a sample of broadly defined industries in the consumer goods-manufacturing sector for the 1954–57 period. Their approach yielded an estimated monopoly overcharge to consumers of 5.5% to 6.0% of value added (p. 242). Unlike all the aforementioned studies which use accounting cost and profit data as their starting point, there are a number of estimates of overcharges based upon price data. For example, Parker (1969), using Bureau of Labor Statistics price data, computed a 15% price-fix overcharge which for the decade 1955 to 1965 cost consumers of bread in western Washington state $30 million annually. Marion, using a structure-price model of metropolitan area food-retailing markets, calculated a 1974 loss to consumers of $662 million nationally due to monopoly in the food-retailing industry.

We have calculated the monopoly loss to consumers of processed foods using three different approaches. These are (*a*) the "loss-components" method; (*b*) price-cost margin estimates; and (*c*) the national brand-private label food price difference method. The three overcharge estimation approaches differ widely and make use of distinct data sets.

The Loss-Components Estimates

Scherer's preeminent textbook in the field of industrial organization presented a set of estimates of the total consumer loss due to market power in the U.S. economy circa 1966 that have been widely cited. He arrived at a total loss figure by considering separately ten different components of consumer loss. His percentage loss for each component was based on an exhaustive review of individual industry studies. Admitting it to be inherently "iffy" and subjective, his "conservative best-guess estimate . . . of the efficiency losses attributable to collusion, the exercise of market power, and related breakdowns of competitive pricing process" was 6.2% of U.S. GNP (p. 408). In addition, he estimated that the redistribution loss of consumers due to monopoly profits is on the order of 3.0% of GNP (p. 409).

Scherer's estimation categories and some of his percentages were adjusted for the U.S. food-manufacturing industries for 1975 (see appendix A of Parker and Connor for details). A summary is shown in table 1. The first component, the income transfer from consumers to monopolists, was calculated by making use of prior regression estimates of market structure-profit relationships for food manufacturing (Federal Trade Commission 1969), substituting, however, the most recent structural data and value of shipment weights. A competitive profit rate was for an industry with 40% four-firm concentration, equal market shares among the top four, and a media advertising-to-sales ratio of 0.5%. The second category, wasteful promotional activities in food, was based on estimates calculated from actual food advertising data for 1975. The procedure involved calculating an advertising-to-sales ratio for the competitive food industries. The competitive advertising rate (0.5%) was then subtracted from actual rates and the remainder defined as excess. The remaining categories of loss due to X-inefficiency were Scherer's estimates adjusted upward on the assumption that X-inefficiency is proportional to the relative degree to which average concentration in the food-manufacturing industries exceed that of all manufacturing. On the basis of both weighted concentration and relative advertising intensities, food manufacturing is more oligopolistic. Two categories of losses were omitted because they do not apply to food processing: deadweight losses in the regulated industries and deficient cost controls in the defense and space industries. The last component, the "deadweight" loss, is among the smallest of the categories. We have deflated Scherer's deadweight loss estimate by assuming a much less elastic demand for food

Table 1. The Loss-Components Estimates of Total Consumer Losses Due to Market Power in the U.S. Food-Manufacturing Industries, 1975

Type of Loss	Scherer's Original Estimate as a Percentage of U.S. GNP, circa 1965	Adjusted Estimates for the Food Manufacturing Industries, 1975: Percentage of Value Added	Percentage of Shipments	Consumer Losses ($ Millions)
1. Income redistribution due to monopoly profit transfers	3.0	7.5	2.1	3,613[a]
2. X-inefficiency due to excess and wasteful advertising and promotional expenses	1.0	8.3	2.3	4,000[b]
3. X-inefficiency due to				
a. lack of cost controls in firms insulated from competition	2.0	6.0[c]	1.7	2,890
b. production at suboptimal scale	0.3	0.9[c]	0.3	430
c. cross-hauling costs and nonoptimal location decisions due to collusive pricing	0.2	0.6[c]	0.2	290
d. chronic excess capacity due to cartelization, collusion, or other monopolistic behavior	0.6	1.8[c]	0.5	870
4. Deadweight and X-inefficiency in the regulated and defense industries	1.2	0.0	0.0	0
5. Deadweight social welfare loss due to monopolistic overpricing and underproduction, unregulated sectors.	0.9	0.9[d]	0.2	430
Total	9.2	26.0[e]	7.3	12,523

[a] Estimate for 1975-based regression equation from Federal Trade Commission (1969).
[b] Assuming $CR4 = 40\%$ as a rough competitive standard, food industries meeting that standard had a media advertising-to-sales ratio of 0.40% (or 0.53% for a total advertising-to-sales ratio). After netting out 0.53% of total domestic sales to consumer processed foods from total advertising expenditures for processed foods, the result is $2,800 million in excess advertising. Because advertising accounts for about 70% of all promotional expenditures, the latter is estimated to be $4,000 million.
[c] All inefficiency components are assumed to be proportional to excess concentration. All of manufacturing has a weighted four-firm concentration ratio ($CR4$) of 44%, or 10% above the assumed competitive standard of 40%. However, food manufacturing's $CR4$ is 52%, which is 30% above the competitive standard, or three times the rest of manufacturing.
[d] Scherer assumed that the long-run price elasticity of demand for an industry's output was −2.5. Studies of comparable elasticities for manufactured food products defined at approximately the four-digit SIC level range from −.3 to −2.8, but most fall within the −.5 to −.8 range. A conservative assumption is −.5.
[e] Expresses consumer loss as a proportion of industry value added. It is the best value measure generally available for comparing the relative economic importance of manufacturing among industries (BOC 1972). Yet the authors realize that some of the sources of the overcharge are not part of industry value added. Examples would include purchased advertising services, packaging materials, cross-hauling by independent truckers, and all of the allocative loss.

(−0.5) than he did for other industries in the economy (−1.0). The aggregate of these component estimates is a consumer loss amount that represents 7.3% of food industry shipments, or $12.5 billion in 1975.

Scherer himself placed a confidence band about his estimate of consumer loss that implied a range of about 5% to 18% of GNP. We feel that because of the two direct estimates made (61% of the total overcharge amount), the total estimate presented in table 1 has a smaller range of error. The components of X-inefficiency adjusted from Scherer contain some assumptions on which reasonable men might differ, but it is extremely unlikely that the levels of X-inefficiency in food manufacturing are less than those of the rest of manufacturing. Price-fixing is rife in many local-market food-processing industries (Marion). The soft drink industry has territorial restrictions that effectively segment markets. Cross-hauling and nonoptimal location decisions are characteristic of several food industries, such as milk. And excess capacity for strategic reasons is known to be serious in the beer industry and others with high fixed costs. For these reasons, we are quite confident that this approach yields a total consumer loss estimate of $12.5 billion that is accurate to within $3 billion.

Price-Cost Margin Estimates

In a 1968 monograph, Collins and Preston examined the relationship between market structure and price-cost margins in food manufacturing. They found a close statistical relationship between the lack of competition and high

price-cost margins in thirty-two food and kindred products manufacturing industries using 1958 Census data. Because higher margins are included in the prices purchasers pay, the present authors have defined the excess in margins due to the lack of competition as the consumer overcharge.

Price-cost margins (*PCM*) are the total dollar amount of value added in an industry less payroll and other direct costs (U.S. Department of Commerce 1972). Therefore, included within the price-cost margins are returns to capital, executive salaries, and expenditures for advertising and other contract services. The overcharge portion of a price-cost margin would include monopoly profits, high salaries of executives, excessive advertising, and costs due to inefficient utilization of capital equipment and contract services.

Collins and Preston used the four-firm industry concentration ratio (*CR*) as an index of monopoly in their model. The present authors accept this role for concentration and define monopoly overcharge as the amounts of interindustry variation in the price-cost margins explained by variation in concentration, other factors held constant. In computing overcharges from the regression models, industries with four-firm concentration levels of up to 40% are considered effectively competitive. As with the loss-components approach, only margin amounts greater than that which corresponds to the competitive level of concentration are considered overcharges.

The variables used to control for other factors in the Collins-Preston model were a capital-output ratio (*K/Y*) and a geographic-market index (*GEOG*). The capital-output ratio was introduced to adjust for differences in capital intensity among industries. The geographic-market index was introduced to take account of the fact that national concentration ratios understate actual levels of concentration in industries whose markets are local or regional in character.

When the model was fitted to the 1958 data using multiple regression analysis, the coefficients in the Collins-Preston equation all had the expected signs and were statistically significant. The best fit of concentration was the nonlinear form involving both *CR* and CR^2. The equation shows that the lowest price-cost margin occurs when *CR* equals 20%, which is half the level the present authors assume as the competitive level. The least squares estimates are shown in equation (1), with *t*-values given in parentheses.

$$(1)\quad PCM = \underset{}{15.699} - \underset{(-1.45)}{.274\,CR} + \underset{(3.75)}{.007\,CR^2} - \underset{(-4.62)}{.121\,GEOG} + \underset{(3.68)}{.250\,K/Y}.$$

The present authors refitted the Collins-Preston model to 1972 Census data for forty-one food-manufacturing industries (appendix table C.1 of Parker and Connor). The coefficients again had the expected signs and were statistically significant except for the linear term of *CR*. The refitted equation (2), which explained 80% of the variation in *PCM*, also shows that the lowest *PCM* occurs when *CR* equals 20%.

$$(2)\quad PCM = 22.096 - \underset{(-.69)}{.211\,CR} + \underset{(1.78)}{.00054\,CR^2} - \underset{(-3.16)}{.117\,GEOG} + \underset{(3.52)}{.178\,K/Y}.$$

In addition to refitting the Collins-Preston model in its original form, the present authors augmented the model by adding several variables suggested by more recent research (Rhoades and Cleaver, Weiss, Strickland and Weiss, and Kwoka). The Parker-Connor model is shown in equation (3). Variables for advertising as a percentage of sales (*ADS*4) of the four largest firms in each industry and for industry growth (*GROW*) were added. The coefficients of all of the variables in the equation had the expective positive signs. In addition to the above, the coefficients of two other variables measuring economies of scale and the intensity of TV advertising had the anticipated signs (negative and positive, respectively), but were not included in the estimating model because they were not statistically significant.

$$(3)\quad PCM = 4.48 + \underset{(3.49)}{.191\,CR} + \underset{(3.64)}{3.695\,ADS4} - \underset{(-1.80)}{.168\,\mathrm{ADS4}^2} - \underset{(-3.07)}{.085\,GEOG} + \underset{(5.97)}{.232\,K/Y} + \underset{(.90)}{.0638\,GROW}.$$

Each of the three equations was used to derive percentage overcharge estimates. The coefficients of the structural variables in the equations were used to calculate the extent to which a price-cost margin for an industry was above that predicted for a competitively struc-

tured industry. The dollar value of overcharge for the industry was calculated by multiplying the percentage overcharge by the industry's 1975 value of product shipments. The total overcharge for all food and kindred products industries was the sum of the individual industry estimates. Table 2 summarizes these estimates.

In order to show the sensitivity of the estimates to the choice of competitive level of concentration, three estimates were calculated from each equation (table 2). In each of the equations *GEOG* is set at 100, which is its modal value for industries that have not been identified as local market industries (National Commission on Food Marketing 1966a). The competitive value of *ADS*4 was set at 0.5%. *K*/*Y* and *GROW* are held constant at their sample means because they are not market structure variables. The predicted values of overcharge therefore abstract from differences among industries due to variations in capital intensity and growth.

The total overcharge estimates from three estimating equations, using 40% as the competitive concentration ratio, range from $12.2 billion to $13.6 billion. The highest estimate is from equation (3). Equation (3) is the most completely specified and also shows the least variability in overcharge amounts due to the choice of the level of concentration defined as competitive. Although the authors believe that the estimate from equation (3) is superior, they wish to maintain a conservative stance by choosing the simple average of the three estimates, $12.9 billion. The deadweight loss that is added to it to arrive at an estimate of total consumer loss is based on the further conservative assumption that demand elasticities in each industry are −0.5. With this assumption the deadweight loss calculates to $823 million and brings the total consumer loss amount to $13,756 million.

Table 2. Total Dollar Amounts of Monopoly Overcharge in the Food-Manufacturing Industries, Estimated from Three Price-Cost Margin Regression Equations, 1975

	Estimated Total Overcharge Amounts when the Competitive Level of 4-firm Industry Concentration is		
Regression Models	35%	40%	45%
		($ billions)	
(1) Collins-Preston equation (1958 parameters)	15.1	13.0	10.4
(2) Collins-Preston equation (1972 parameters)	13.8	12.2	10.2
(3) Parker-Connor equation	15.0	13.6	12.7
Average	14.6	12.9	11.1

National Brand-Private Label Price Difference Estimate

In this method, prices of food-chain private labels are considered to approximate competitive prices; the amounts by which manufacturer brand prices exceed private label prices for the same items and which can be attributed to departures from perfect competition are considered to be estimates of monopoly overcharges. The dollar overcharge for a product category is the percentage of overcharge times the wholesale value of manufacturer-brand sales. The overcharge is attributed only to manufacturers. Only to the extent retailers might pyramid or absorb the manufacturers' overcharge would retailers affect the value of the overcharge. It is assumed that over-pricing by retailers due to local market monopoly positions held (Marion et al.) would apply equally to national brands and private labels.

The private label-national brand price-estimating method cannot be easily applied outside of the grocery products area. In addition to the availability of comparable private label-manufacturer brand price data for a large number of different products, the analysis of the data is made possible by the fact that both national brand and private label products are often manufactured by the same firms to the same specifications, move through market channels in a parallel manner, and encounter few differences in transportation, inventory, warehousing, or in-store merchandising.

Manufacturer brands predominantly are sold nationwide and are supported by large-scale national advertising. In this paper we use the terms "advertised brand," "national brand," "manufacturer's label," and similar variants interchangeably. We also regard "house brand," "controlled label," "retailer brand," "distributor's brand," and "private label" as essentially equivalent terms. "Generic" products, which are packaged items displaying no brand name of any kind, are a special form of private label, but these items did not exist in U.S. grocery stores in

1975. Akin to the generics are the "fresh" meat and fresh produce items in grocery stores, virtually all of which are unbranded items.

Private label products clearly account for a large portion of U.S. grocery store sales. Based on the records of grocery warehouse shipments, the private label share for all processed foods was 16.4% nationally in 1975. If one adds all fresh meat and produce (virtually all private label products) and all nonfood products sold through grocery stores (about 8.2% private label), then fully 39.3% of all U.S. grocery stores sales consisted of private label (or unlabeled) products in 1975.

We recognize that some private labels have achieved wider geographic national distribution than some manufacturer's brands. Also, some private label lines are occasionally given advertising support by the retailers that own them, while a few brands of leading national manufacturers go unadvertised. Nevertheless, in almost all cases the distinction between nationally advertised brands and private labels is unambiguous.

It is assumed that national brands sell at premiums which manufacturers set in accordance with the strength of preference created by advertising and other promotion. Their ability to achieve such prices is enhanced when sales of manufacturer brands are concentrated within a few firms. Advertising is also a principal barrier to entry into food-manufacturing markets. The blockading effect of the advertising barrier is buttressed when the advertising is mainly on television and when it is controlled by large diversified firms who can coordinate it with the activities of large field sales forces. An important problem related to advertising and promotion is the difficulty faced by smaller food manufacturers in obtaining shelf space. In the struggle over shelf space, the small manufacturer faces nearly insurmountable odds (Walzer et al.). Heavy introductory advertising and couponing presell the products of large manufacturers to consumers, virtually forcing retailers to carry the products. Retailers who control shelf space have great discretion in allocating it to their own private labels.

Although large food chains do a considerable amount of food manufacturing, most private label products are purchased. Suppliers are mainly medium-sized and smaller food manufacturers, and purchases are made with price as the primary factor. Food chains have considerable information concerning quality and most of their purchases are bought strictly on a specification basis (NCFM 1966b, p. 133). It is assumed that retailers can obtain private label items at or near the minimum necessary costs of production.

Private label products are usually advertised only in newspapers, with these ads generally featuring price. The average advertising-to-sales ratio for private label products is judged by the authors to be substantially less than the total food chain advertising-to-sales ratio of about 1%, which includes advertising for nonmanufactured products, the company name, coupons, and other store merchandising programs. The actual private label advertising-to-sales ratio probably would be in the neighborhood of the 0.5% calculation used above as the competitive level of food advertising for national brands.

To the extent there are physical quality differences between private labels and national brands, the differences in their prices would imperfectly reflect monopoly overcharges. Available studies comparing quality have concluded that average quality differences are minimal (Federal Trade Commission 1933, Bureau of Economics and Business Research, Jafri and Lifferth, and NCFM 1966b). A painstaking review of several quality tests concluded that "distributors' and manufacturers' brands are essentially equal in quality" (Applebaum and Goldberg, p. 47). Most of these studies are rather dated, and Jafri and Lifferth is based on a rather small sample. Also, in the present authors' judgment, the studies have been biased toward commodity-type products, like canned fruits and vegetables, leaving open the possibilities that quality differences exist between private labels and national brands of highly processed products or that private label products have more variability in quality.

The authors believe the magnitude of such a potential bias is limited by the fact that the food industries are generally low-technology industries whose plants are not significantly affected by scale requirements. Thus, entry by larger retailers is not forestalled by scale barriers. Further, studies of actual private label policies have found that a high quality image for private label merchandise is considered important: "normally retailers' top-line private label merchandise is intended to be of a quality equal to or better than the quality contained in national brands with which they

compete in their marketing area" (NCFM 1966b, p. 133). This finding still leaves the possibility that second-line private label products are of somewhat lower average quality. The very recent introduction by grocery chains of so-called generic products, which are of distinctly lower grades, illustrates this possibility (Walzer et al.).

The combined sales of truly national brand and private label products account for nearly all food product sales through grocery stores (NCFM 1966c, p. 35). The only significant exceptions are several food-processing industries which are organized through local markets because of high perishability of products or high transportation costs. For products like fluid milk and bread, there are often local brands which have "consumer franchises" as strong as the leading national brands of the product.

The data used as measures of the price differences between private labels and manufacturer brands, and also private label market shares, are from a special study of 1976 prices by Selling Area-Marketing, Inc., a subsidiary of Time, Inc. (SAMI). From SAMI data, it was possible to tabulate average manufacturer brand price premiums and private label sales shares for forty-one 5-digit food product classes (Siegfried. These data and details on all other variables discussed can also be found in appendix D of Parker and Connor.) By multiple regression techniques, the authors fitted an equation relating manufacturer brand price premiums to market structure variables measuring the degree of monopoly in product classes. The price difference values predicted by the structural variables in the equation are monopoly overcharge percentages. Random variation and that portion of the price difference variation attributable to the nonstructural variables does not enter into the overcharge estimate. A very similar model was developed and tested using United Kingdom data by Nickell and Metcalf.

In constructing the price differential model, the private label-national brand price difference (*DIFF*) was hypothesized to be greater: the greater the advertising-to-sales ratio of the four leading firms (*ADS*4) in the product class, the more important TV advertising was to total advertising (*TVADV*) and the greater the proportion of advertising done by big firms (200*ADV*). In this case, big firms were the 200 largest food and tobacco manufacturing companies in 1975 (Connor and Mather). Concentration (*CR*4) was hypothesized to increase the price differential; however, it was introduced as a nonlinear term to reflect the general findings of structural-performance studies (Weiss). The Collins-Preston variable measuring geographic distribution of production relative to the distribution of the population (*GEOG*) was introduced to adjust the concentration ratio to market size (Collins and Preston, p. 120). A low value of the variable means similar distributions and a likelihood that national concentration ratios understate true concentration. A net import variable (*NETIMP*) also was introduced as a correction to concentration. Imports are the equivalent to adding additional domestic products to the denominator of a concentration ratio. Therefore, its sign in regression should be the opposite of that of the concentration ratio. Real growth (*GROW*), domestic consumer sales of the product class (*LNSIZE*), and number of manufacturers (*LNFIRMS*) were introduced to capture other differences affecting the price differential. Since private labels generally are considered "me too"-type brands, a rapidly growing product area should see manufacturer brand prices high, riding the tide of brisk demand, and facing little price competition from private labels. Large total sales of the product class, on the other hand, signal a mature product area and the likelihood of a well-established private labels supply. A large number of potential suppliers is also posited to signal a likelihood of well-established private labels and a large number of potential competitors for the national brand manufacturers. If the private label fringe collectively garners a significant portion of the market, price retaliation by the national brand manufacturers is likely (Scherer, p. 186). Thus, the expected signs of *LNSIZE* and *LNFIRMS* are negative.

The estimated price difference regression equation supported the hypothesized predictions for each of the variables (equation 3.1 of table 3). All the terms were statistically significant (except for *GEOG*), and the fitted equation explained nearly three-fourths the variation in the private label-national brand price differences. The good fit strongly supports our hypothesis that national brand price premiums are related to competitive conditions in food-manufacturing industries, and because of this we feel it provides a means for calculating reliable and disaggregated estimates of monopoly overcharges.

Table 3. Regression Results Explaining the Market Structure Determinants of National Brand-Private Label Price Differences and the Private Label Market Share in 1975

$$
\begin{array}{ll}
(3.1) & DIFF = \underset{(.252)}{3.362} + \underset{(2.443)^{***}}{.630\ CR4} - \underset{(-2.443)^{***}}{.0051\ (CR4)^2} \\
 & \quad - \underset{(-1.035)}{.0394\ GEOG} + \underset{(1.626)^{*}}{.909\ ADS4} \\
 & \quad + \underset{(2.941)^{***}}{17.194\ TVADV} + \underset{(2.665)^{***}}{.179\ 200ADV} \\
 & \quad + \underset{(1.624)^{*}}{6.824\ GROW} - \underset{(-2.510)^{***}}{2.426\ LNSIZE} \\
 & \quad - \underset{(-2.238)^{**}}{2.038\ LNFIRMS} - \underset{(-2.156)^{**}}{17.362\ NETIMP}, \\
 & \qquad R^2 = 0.72,\ F = 7.73^{***} \\
(3.2) & SHARE = \underset{(9.605)^{***}}{36.003} - \underset{(-3.781)^{***}}{.2156\ CR4} - \underset{(-4.331)^{***}}{2.312\ ADS4}, \\
 & \qquad R^2 = 0.94,\ F = 94.88^{***}
\end{array}
$$

Note: Both equations were run using 41 5-digit product classes as observations. Numbers in parentheses are t-values. Asterisks indicate increasing order of statistical significance: * is 10% level; ** is 5% level, and *** is 1% level. The share equation was corrected for heteroskedasticity. The variable definitions (and data sources) are as follows:

DIFF, the percentage that average private label price is lower than average manufacturer brand price (SAMI); *SHARE*, average private label share of grocery store sales of product class (SAMI); *CR*4, four-firm concentration ratio of product class (BOC 1972); *GEOG*, index used to correct *CR*4—a low value means production is distributed according to population and markets are regional or local rather than national (BOC 1972); *ADS*4, advertising expenditures on eight measured media, supporting brands of four largest firms, divided by their estimated consumer sales, 1975 (Connor); *TVADV*, national network television advertising expenditures as a proportion of total measured media advertising (Connor); 200*ADV*, percentage of four-largest-firm advertising done by firms ranking among 200 largest food and tobacco manufacturing companies, 1975 (Connor); *GROW*, real growth in output 1967 to 1972 (BOC 1972); *LNSIZE*, natural log of 1975 domestic consumer sales of product class (BOC 1975); *LNFIRMS*, natural log of 1972 companies in industry (BOC 1972); *NETIMP*, net imports minus exports as a percentage of value of shipments (BOC 1971).

SAMI private label sales shares were regressed on advertising-to-sales ratios and concentration ratios. More complete share equations were fitted, with the coefficients of the independent variables generally showing the correct (opposite) predicted signs.[6] However, variables other than concentration and advertising were statistically insignificant. The simplest equation was therefore selected.[7] The share equation was then used to predict private label shares from which their complements, manufacturer brand shares, were calculated for those product classes where SAMI data were missing. The estimated manufacturer brand sales used in calculating monopoly overcharge are 1975 census values of shipments for the product classes, adjusted for exports and imports, reduced by estimated sales to nongrocery retailers, and reduced by private label sales.

Thus, the dollar overcharge for a product class is manufacturer-brand domestic sales times the percent overcharge. The estimate of the overcharge rectangle (P_mP_cRM in figure 1) for all food and kindred product industries is the sum of the overcharges for all 5-digit product classes. Using the predicted values of the percentage overcharge and manufacturer brand sales, estimates were made for all product classes except "not specified by kind" (see appendix table B.1 of Parker and Connor). The amount of consumer loss attributed to the deadweight loss triangle (*MRC* on figure 1) was calculated using the conservative assumption that demand curves had an average elasticity of −0.5.

The total consumer loss due to monopoly in food and kindred products industries, based on the private label-manufacturer brand price differential model, was $12,436 million. This including a $11,877 million estimate for the overcharge rectangle and $559 million deadweight loss. This estimate is conservative because it encompasses only domestically produced food products sold through grocery stores. It excludes the approximately 30% of food manufacturer sales through restaurants and other mass feeding institutions, animal feeds, and sales that become inputs in more highly processed foods. The overcharges in these transactions eventually get passed on to consumers, but are not captured by our analysis. We have not applied our regression coefficients to estimate overcharges in nonconsumer transactions because we feel that buyers in these markets are much better informed than ordinary consumers and often their monopsony power partly countervails the monopoly power of sellers. The use of those coefficients would have overstated the

---

[6] The authors considered the possibility that price differences (*DIFF*) and private label share (*SHR*) were mutually determined, but experiments with simultaneous equation models did not prove fruitful. Moreover, heteroskedasticity was found in one equation (the share equation), and the authors are not aware of any econometric methods that permit a weighting scheme to be applied to a system of simultaneous equations.

[7] From an examination of the residuals, e_i, of the ordinary least squares (OLS) regression of the private label share equation, we found that both *CR*4 and *ADS* were quite clearly related to increasing variance of the e_i. To correct this heteroskedasticity, let $e_i^2 = \alpha(CR4)^{\beta_1}(ADS)^{\beta_2}$, $e_i^2 = \alpha(CR4)^{\beta_1}$, or $e_i^2 = \alpha(ADS)^{\beta_2}$ and estimate by OLS its double log transform. The last model was found to perform best and $\hat{\beta}_2 = 1.812$ was significantly different from zero. Hence, the appropriate weight to impose homoskedasticity on the share equation is $(ADS)^{-\beta_2/2}$ or $ADS^{0.906}$. A reexamination of the pattern of the residuals of the weighted equation confirmed the validity of this scheme. It should be noted that, prior to weighting, the private label share equation explained 58% of the variation.

effect of concentration, advertising, and other variables on the overcharge. By leaving non-grocery store sales out altogether, we have admittedly erred in the other direction, understating the actual total consumer loss by significant amounts.

Another source of underestimation error involves our assumption that private label prices are proxies for competitive prices. Private label prices are probably higher than competitive levels, particularly when competing manufacturer brands are highly advertised. Not only is there a possibility that retailers may enjoy higher net profits from their private label sales, but a substantial likelihood that retailers' procurement prices may contain elements of monopoly overcharge (Parker 1976). In addition, private labels generally have higher retail gross margins to cover their greater allocation of shelf space and slower turnover rates. To counter the advertising support behind manufacturer brands, retailers generally merchandise private labels by assigning them larger quantities of scarce and expensive-to-maintain shelf space (Walzer).

Despite these caveats relating to the use of *DIFF* as a proxy for consumer overcharge, we believe the results are sufficiently reliable to warrant its consideration as a basis for formulating competition policy with respect to grocery products. Moreover, the method permits the computation of consumer overcharges of narrowly defined product lines, unlike most previous approaches.

Summary and Conclusions

A summary of the three estimates is shown in table 4. The authors believe the estimates are conservative. However, because of the data sets used and because of the estimating procedures employed, a considerable degree of error is likely for each of the estimates. Scherer, for the whole economy, thought that the maximum error would fall within the range of 50% less to 100% greater than his estimate. The present authors have used statistically fitted structure-performance relationships and data specific to food manufacturing to estimate Scherer categories comprising about 60% of the total consumer loss estimate. The estimated values of these components are believed to be more reliable than Scherers' original values and should tend to reduce the error range of the overall loss estimate. The authors have no method for estimating the likely error

Table 4. Summary of Monopoly Loss Estimates in U.S. Food Manufacturing, 1975

Type of Consumer Loss	Loss Components (Adjusted)	Price-Cost Margin	Private Label Differential
	($ millions)		
Monopoly profit	3,613	12,933	11,877
X-inefficiency	8,480		
Allocative	430	823	559
Total	12,523	13,756	12,436

range of their two additional methods. They feel, however, that a 25% error on the two estimates is the most that would reasonably be expected. The extent of convergence of all three essentially independent estimates gives strength to the conclusion that consumer loss due to monopoly in the U.S. food-manufacturing industries in 1975 was at least $10 billion, but possibly as high as $15 billion.

To put these estimates in perspective, recall that Scherer ventured that the monopoly loss to consumers in the whole economy was 9% of GNP; with U.S. GNP running at $1,500 billion in 1975 (Council of Economic Advisors 1977), this implies an overcharge of some $135 billion (or $120 billion if he meant to include only the private sector of the economy). For food manufacturing, our estimate is equal to one-fourth of the total GNP (value added) attributed to the sector. However, put another way, our monopoly loss estimate for processed foods represents 1.1% of U.S. personal disposable income and about 5.7% of average U.S. household food expenditures in 1975.

There are significant implications of our monopoly loss estimates for public policy. The annual loss to consumers in food manufacturing alone is 250 times the combined antitrust budgets of both U.S. antitrust agencies and several thousand times that part of federal antitrust expenditures.

Besides demonstrating that food processing ought to have a high priority for the antitrust agencies, the findings of our price-cost margin and national brand-private label price models suggested that advertising represents an important problem area for consumer products. Furthermore, the problem is most serious when TV is the primary medium and when the advertisers are large firms. This suggests that consideration be given to limiting advertising in industries where it is already intense and to formulating stricter policies that would dis-

courage product extension mergers where differentiated consumer products are involved. This latter suggestion is further supported by evidence that food-manufacturing mergers on average exhibit a subsequent doubling of advertising outlays (NCFM 1966a), often accompanied by a shift toward greater use of TV. An antitrust policy or a new law that reduces food company mergers, especially takeovers by leading grocery product firms and other conglomerates, would be expected to moderate the market power of sellers by its effect on both concentration and advertising.

However, we recognize that neither advertising restrictions nor merger prohibitions may erode this existing market power at sufficient speed to achieve workable competition in all food-manufacturing industries. Under these circumstances, therefore, more direct restructuring may be necessary. Such restructuring could take the form of divestiture of portions of the physical assets of leading firms, compulsory licensing of major trademarks, or other affirmative programs to encourage the entry of firms into the affected markets.

[*Received January 1979; revision accepted March 1979.*]

References

Applebaum, William, and Ray A. Goldberg. *Brand Strategy in United States Food Marketing.* Boston: Harvard Graduate School of Business Administration, 1967.

Bain, Joe E. *Barriers to New Competition.* Cambridge, Mass.: Harvard University Press, 1956.

Bell, Frederick W. "The Effect of Monopoly Profits and Wages of Prices and Consumer's Surplus in U.S. Manufacturing." *West. Econ. J.* 6(1958):233–41.

Bureau of Economic and Business Research (BEBR). *Manufacturer and Distributor Brands.* Urbana: University of Illinois, 1955.

Collins, Norman R., and Lee E. Preston. *Concentration and Price-Cost Margins in Manufacturing Industries.* Berkeley: University of California Press, 1968.

Comanor, William S., and Harvey Leibenstein. "Allocative Efficiency, *X*-inefficiency, and the Measurement of Welfare Losses." *Economica* 36(1969):392–415.

Comanor, William S., and Thomas Wilson. *Advertising and Market Power.* Cambridge, Mass.: Harvard University Press, 1974.

Connor, John M. *Competition and the Role of the Largest Firms in the U.S. Food and Tobacco Industries.* USDA ESCS, 1979.

Connor, John M., and Loys Mather. *Directory of the 200 Largest Food and Tobacco Processing Companies, 1975.* USDA, 1978.

Council of Economic Advisors. *Economic Report to the President 1976.* Washington, D.C., 1977.

Currie, John M., John A. Murphy, and Andrew Schmitz. "The Concept of Economic Surplus and Its Use in Economic Analysis." *Econ. J.* 81(1971):741–99.

Dixit, Avinash, and Victor Norman. "Advertising and Welfare." *Bell. J. Econ.* Spring (1978), pp. 1–17.

Doyle, Peter. "Economic Aspects of Advertising: A Survey." *Econ. J.* 8(1968):570–602.

Dupuit, J. "On the Measurement of Utility of Public Works." *Annales des Ponts et Chaussees* 8(1844).

Federal Trade Commission (FTC). *Chain Stores: Chain Store Private Brands.* Washington, D.C., 1933.

———. *The Influence of Market Structure on Profit Performance of Food Manufacturing Companies.* Washington, D.C., 1969.

Harberger, A. C. "Monopoly and Resource Allocation." *Amer. Econ. Rev.* 44(1954):77–87.

Jafri, Syed Hussain, and Dennis Lifferth. *Prices and Quality Comparisons of National Brand and Private Label Food Products.* New York: Dep. Agr. Econ. Staff Pap. 77-11, Cornell University, 1977.

Kamerschen, David R. "An Estimation of the 'Welfare Loss' from Monopoly in the American Economy." *West. Econ. J.* 4(1966):221–36.

Kwoka, John E. "The Effect of Market Share Distribution on Industry Performance." *Rev. Econ. and Statist.* 61(1979):101–9.

Leibenstein, Harvey. "How Inefficiency Saps Corporate Profits." *Fortune*, 19 June 1978a, pp. 209–10.

———. "*X*-Inefficiency *X*ists." *Amer. Econ. Rev.* 68 (1978b):203-11.

Lerner, Abba P. "The Concept of Monopoly and the Measurement of Monopoly Power." *Rev. Econ. Stud.* 1(1934):157–75.

Levinson, H. M. "Postwar Movement in Prices and Wages in Manufacturing." *Study of Employment, Growth and Price Levels.* U.S. Congress, Joint Economic Committee Stud. Pap. No. 21, 1960.

Marion, Bruce. "Government Regulation of Competition in the Food Industry." *Amer. J. Agr. Econ.* 61 (1979):178–87.

Marion, Bruce, Willard F. Mueller, Ronald W. Cotterill, Frederick E. Geithman, and John R. Schmelzer. *The Food Retailing Industry: Structure, Profits, and Prices.* New York: Praeger Publishers, 1979.

Marshall, Alfred. *Principles of Economics.* London: Macmillan & Co., 1930.

National Commission on Food Marketing (NCFM). *The Structure of Food Manufacturing.* Tech. Stud. No. 8. Washington, D.C., 1966a.

———. *Organization and Competition in Food Retailing.* Tech. Stud. No. 7. Washington, D.C., 1966b.

———. "Private Label Products in Food Retailing." *Special Studies in Food Marketing.* Tech. Stud. No. 10. Washington, D.C., 1966c.

Nickell, Stephen, and David Metcalf. "Monopolistic Industries and Monopoly Profits or, Are Kellogg's Cornflakes Overpriced?" *Econ. J.* 88(1978):254–68.

Parker, Russell C. "The Baking Industry." *Antitrust Law & Econ. Rev.* 2(1969):111–22.

———. *The Status of Competition in the Food Manufac-*

turing and Food Retailing Industries. Work. Pap. No. 6. NC-117, 1976.

Parker, Russell C., and John M. Connor. "Estimates of Consumer Loss Due to Monopoly in the U.S. Food Manufacturing Industries." NC-117 Working Paper No. 19. Food Systems Research Group, Dep. Agr. Econ., University of Wisconsin-Madison, Sep. 1978.

Peterbin, Betty B. "The Dietary Goals and Food on the Table." Paper presented at the USDA Food and Agricultural Outlook Conference, Washington, D.C., 19 Nov. 1977.

Posner, Richard A. "The Social Costs of Monopoly and Regulation." *J. Polit. Econ.* 83(1975):807–27.

Rhoades, Stephen, and Richard Cleaver. "The Nature of the Concentration-Price/Cost Margin Relationship for 352 Manufacturing Industries: 1967." *S. Econ. J.* 27(1973):1062–75.

Scherer, F. M. *Industrial Market Structure and Economic Performance*. Chicago: Rand-McNally & Co., 1970.

Selling Areas-Marketing, Inc. (SAMI). *Special SAMI Study: Difference between Price per Pound Nationally for Private Label and Advertised Brands in Selected Product Categories*. Chicago, 1977.

Siegfried, John J. *Selling-Area Marketing, Inc. Market Share Data*. Paper presented at the Industrial Organization Society session of the Allied Social Sciences Association annual meeting, Chicago, 29–31 August 1978.

Siegfried, John J., and Thomas K. Tiemann. "The Welfare Cost of Monopoly: An Inter-industry Analysis." *Econ. Inquiry* 12(1974):190–202.

Strickland, Allyn, and Leonard Weiss. "Advertising, Concentration and Price-Cost Margins." *J. Polit. Econ.* 84(1976):1109–21.

Stigler, George J. "The Statistics of Monopoly and Merger." *J. Polit. Econ.* 64(1956):213–16.

U.S. Congress, Senate, Select Committee on Nutrition and Human Needs. *Dietary Goals for the United States*. Washington, D.C., Jan. 1977.

U.S. Department of Commerce, Bureau of the Census (BOC). *Annual Survey of Manufacturers*. Washington, D.C., 1975.

———. *Census of Manufacturers 1972*. Washington, D.C., 1972.

Walzer, Ed, Joseph S. Coyle, and Robert E. O'Niell. "Brand Power Study" (series). *Progressive Grocer* Oct., Nov., Dec. 1976.

Weiss, Leonard. "The Concentration Profit Relationship and Antitrust." *Industrial Concentration: The New Learning*, ed. Harvey J. Goldschmid, H. Michael Mann, and J. Fred Weston. Boston: Little, Brown & Co., 1974.

Sharecropping, Production Externalities, and the Theory of Contracts

James Roumasset

Abstracting from transactions costs, the equilibrium bargaining solution with sufficient traders is equivalent to the Walrasian equilibrium. For a sharecropping economy, this proposition establishes the validity of the competitive theory of share tenancy. For an economy with production externalities, the same proposition serves as a nontrivial version of the Coase theorem.

Key words: core of an economy, Lindahl pollution solution, universal markets.

In his most celebrated article, Coase showed that inefficiency is not a necessary consequence of externalities; under well-defined property rights, voluntary arrangements are possible which can internalize externalities. In a similar spirit, Cheung (1969) has shown that share tenancy does not necessarily cause allocative inefficiency; the terms of a sharing arrangement may in fact pay factors their marginal products.

Both contributions can be viewed as different applications of the same point; namely, that under certain conditions, contracts are perfect substitutes for competitive markets. The purpose of the present paper is to illustrate what those conditions are and to show that a related theorem which has been developed and proven by Debreu and Scarf (1963) in another context serves as a solid cornerstone of the theories of sharecropping, production externalities, and contracts in general.

A modified version of the Coase/Cheung proposition is stated in the first section as a corollary of the Debreu-Scarf theorem. Because proofs of the theorem generally rely on advanced mathematics,[1] section two presents a demonstration of the proposition using an example of a simple sharecropping economy. The third section extends the proposition to production externalities. In the concluding section, the main results are summarized and suggestions are made for applying and extending the theory to explain patterns in agricultural contracts.

A First-Best Theory of Contracts

Perhaps the most fundamental concept in the theory of resource allocation is the Walrasian "competitive" equilibrium.[2] The relevance of the Walrasian equilibrium has been much assailed on the grounds that real economic agents do not act as price takers, and, even if they did, there is no strong reason for believing that an equilibrium would be attained. Indeed, the relevance of the Walrasian equilibrium seems to rest on the ad hoc defense of a mythical Walrasian auctioneer (Weintraub).

Roughly a century ago, Edgeworth defended the relevance of the Walrasian equilibrium using the concept of the core of an economy. The Walrasian equilibrium is a noncooperative solution concept based on the notion that agents respond to parametric prices without interagent negotiation. In contrast, the core is a solution concept for cooperative games wherein interagent bargaining is costless. Specifically, the core is the set of unblocked allocations. (An allocation is said to be blocked if some subset of agents can form a

---

James Roumasset is the Philippines representative of the Agricultural Development Council and associate professor at the University of Hawaii.

The author is indebted to Jose Encarnación, Jr., Theodore Groves, Sisira Jayasuriya, William Moss, and Jeffrey Williamson for helpful comments on previous drafts, and to the National Science Foundation for research support under grant number SOC 76-83845, administered by the University of Hawaii.

[1] Debreu and Scarf (1963) and Hildenbrand. Recently, however, Johansen has provided an exposition which relies only on calculus.

[2] As Hildenbrand has noted, "Walrasian equilibrium" is at once more descriptive and more specific than the more conventional "competitive equilibrium."

new coalition whereby it can guarantee that all of its members will be better off.) Edgeworth showed that as the number of consumers in a two-commodity exchange economy is increased, the core "shrinks" until, in the limit, it contains only the Walrasian equilibrium (Debreu and Scarf 1972).

Edgeworth's "limit theorem" was resurrected by Shubik and extended to many commodities and production by Debreu and Scarf (1963). It is now commonly referred to as the Debreu-Scarf theorem. The entire literature on the relationship of Walrasian equilibria and the core, including further extensions, has been reviewed by Hildenbrand. Hildenbrand also credits Aumann for making precise the notion that agents will take prices as given if they have no influence on them. That is, Aumann's "equivalence theorem" shows that given reasonable restrictions on preferences, the set of Walrasian equilibria and the core are identical for an atomless exchange economy.

While the primary interest in the limit theorem has been to establish the relevance of the Walrasian equilibrium, it also serves as the basis for a theory of contracts. Just as the Walrasian equilibrium is a market solution, the core, with its assumption of unrestricted bargaining, can be regarded as a contract solution. Thus, the limit theorem implies that, with many traders, the contract solution is the same as the market solution.

More precisely, we can now state the following proposition:

> If property rights are well-defined and contracting costs are zero, then as the number of agents of each type becomes large, all viable contractual arrangements approximate the Walrasian equilibrium with universal markets, regardless of whether markets exist or not.

This is a corollary of the Debreu-Scarf theorem. How close the approximation is depends on how large is the number of agents. "Universal markets" is used, following Arrow, to mean that markets exist for all commodities and activities which enter into either utility or production functions.[3] The above proposition is a "first-best" theory of contracts in the sense that "second-best" considerations, i.e., transactions costs and other constraints, are ignored.[4]

When the corollary is applied to share contracts, we get Cheung's (1969) proposition that share tenancy allocates resources as if a profit-maximizing farmer hired land and labor from competitive factor markets. When it is applied to production externalities, we get a precise and nontrivial version of the Coase theorem.

The Core of a Sharecropping Economy

Cheung (1969) conjectured that aside from the allocative effects of uncertainty and contracting costs, the equilibrium terms of share contracts will be such that factors are allocated and compensated as if they were hired on competitive factor markets. His reasoning was that if the terms of the share contract were such as to induce inefficiency, then recontracting would occur to exploit that inefficiency. Furthermore, if a landowner or tenant were receiving less than his marginal product, he would take advantage of competition and recontract so as to receive his marginal product.

Cheung's attempt to provide a mathematical proof of this conjecture was not successful, but Reid later proved that if landowners and tenants regard the terms of the contract (labor intensity and the sharing rate) as fixed, then the equilibrium contract terms are those which pay factors their marginal products. Given such terms, the allocation of land and labor will be identical to the competitive market solution. The assumption of contract-term-taking behavior, however, appears to be inappropriate in a one-to-one contractual arrangement such as share contracting, where the contracting parties are frequently in contact. Because the costs of negotiation are relatively low, a bargaining model seems more appropriate.[5]

---

[3] Producers may be classified by "types" according to the commodity produced and their production functions. Consumers may be classified according to their demand functions.

[4] This distinction between first-best and second-best has become common only recently (see e.g., Layard and Walters, sections 6-1 and 6-2). The "theory of the second-best" of the 1950s is "If one of the standard efficiency conditions cannot be satisfied, the other efficiency conditions are no longer desirable" (Layard and Walters, p. 181). In modern technology, a second-best problem involves solving for efficiency conditions with one or more additional constraints to the basic restrictions on technology, resources, and preferences. One such additional constraint has captured the attention of economists recently and has led to a sizeable body of literature known as the theory of optimal taxation. The constraint is that government must generate a fixed amount of tax revenue, but it cannot tax leisure. Second-best efficiency is also referred to as "constrained Pareto optimality." The relationship to the "theory of the second-best" is straightforward because the reason we cannot satisfy one of the first-best efficiency conditions is that there must be at least one additional constraint.

[5] Bell and Zusman also have argued for a bargaining approach, but they have chosen the Nash solution as the appropriate solution concept, assumed that contracts stipulating the amount of labor

Applying the corollary from part one, we see immediately that in a bargaining context, sufficient competition guarantees that the Walrasian equilibrium or Cheung solution is attained even if the landowner and tenant regard the terms of the contract as negotiable. We now turn to a demonstration of this proposition. At the same time we investigate how "fast" the core shrinks to the Walrasian allocation.

Consider a simple one-good (rice) economy consisting of one landowner with land, H, and one tenant with labor, L. Production technology for rice is given by $Q = H^{1/2}L^{1/2}$. Utility of each is assumed to be an increasing function of his own share of the rice production. Because there are no other uses for land and labor, the core solution requires that all land and labor be employed in rice production. The only remaining variable to be established is the landowner's percentage share, r, of the gross harvest. But, because neither the landowner or tenant can guarantee himself any output whatsoever—land or labor must be jointly employed—there is no value of r which can be "blocked" by either tenant or landowner. That is, the core consists of all values from 0 to 1. We denote the core for one landowner and one tenant, C_{11}, as

$$C_{11} = \{r | 0 \leq r \leq 1\},$$

i.e., all values of r such that r is not less than 0 nor greater than 1.

Now consider an economy with two (identical) landowners and two (identical) tenants. Without loss of generality, we further assume that each landowner has one unit of land and each tenant has one unit of labor. A landowner with one tenant working his land therefore receives income equal to r. The extent to which landowners can "exploit" labor, i.e., r_{max}, is limited by the potential of one landowner breaking the coalition with the other and forming a new coalition with the two tenants. r_{max} is that rental share such that if r were to rise any higher, then a coalition of one of the landowners and the two tenants could guarantee themselves a higher payment than in the two-landowners two-tenants coalition. After paying the tenants what they were receiving in the old coalition, the landowner's share in the present coalition is $1^{1/2}2^{1/2} - (1 - r)2^{1/2}2^{1/2} = 2r + 2^{1/2} - 2$. To compute r_{max}, set this residual equal to the income received by each landowner assuming that landowners received equal share in the old coalition, i.e., r. (If they received different shares, then the landowner with the lower share could unite with the tenants and block the old coalition at some level less than r_{max}.) Therefore, r_{max} is the solution of the equation,

$$2r + 2^{1/2} - 2 = r, \text{ i.e.,}$$
$$r_{max} = 2 - 2^{1/2} = .586.$$

To solve for r_{min}, the lowest undominated landowner share, simply reverse the roles of land and labor and investigate how much the tenants can "exploit" their landowners, i.e., how much income they can extract before it becomes possible for two landowners and one laborer to form a blocking coalition. Thus, $r_{min} = 2^{1/2} - 1 = .414$.

The limits of the core for the general case can be derived by induction. For n landowners and n tenants, the relevant blocking coalition (*RBC*) is simply the coalition of all agents excluding one agent with the highest share.[6] In order to prevent the *RBC* from becoming effective, the group with the higher share (landowners or tenants) will divide their joint income equally. If landowners have the advantage, the *RBC* will exclude one of the landowners with an equal share of total landowners' income.

Thus, the *RBC* which limits landowner exploitation is the coalition of n tenants and $n - 1$ landowners, i.e., $RBC_{(n-1),n}$. Therefore, r_{max} is the solution of the equation

$$(n - 1)^{1/2}n^{1/2} - n(1 - r) = (n - 1)r, \text{ or}$$
$$r_{max} = n - (n - 1)^{1/2}n^{1/2}.$$

Similarly, r_{min} is computed with reference to $RBC_{n,(n-1)}$, i.e., r_{min} is the solution of

$$n^{1/2}(n - 1)^{1/2} - nr = (n - 1)(1 - r), \text{ or}$$
$$r_{min} = n^{1/2}(n - 1)^{1/2} - (n - 1) = 1 - r_{max}.$$

This formula was used to simulate the effects of increasing the number of agents on the core. Table 1 shows the limits of the core, r_{max} and r_{min}, for economies with increasing number of agents. It is readily seen that the core

to be applied have no effect on the amount of labor actually contributed, and also assumed that landowners strike independent bargains with each of their tenants (i.e., that a subgroup of tenants cannot bargain as a unit).

[6] For example, in the 6-person game, r_{max} is similarly determined with reference to the 2-landowner, 3-laborer coalition, i.e., the landowner is blocked if r is above the break-even level given by

$$2^{1/2}3^{1/2} - 3(1 - r) = 2r$$
$$r_{max} = 3 - 2^{1/2}3^{1/2} = .551, \text{ and}$$
$$r_{min} = .449.$$

Table 1. Core Shrinking for Equal Number of Landowners and Tenants

n (number of landowners)	r_{max}		r_{min}
1	$1 - 0\sqrt{1}$	$= 1.000$	0.000
2	$2 - \sqrt{1}\sqrt{2}$	$= .586$	.414
3	$3 - \sqrt{2}\sqrt{3}$	$= .551$	.449
4	$4 - \sqrt{3}\sqrt{4}$	$= .536$	.464
5	$5 - \sqrt{4}\sqrt{5}$	$= .528$	.472
10	$10 - \sqrt{9}\sqrt{10}$	$= .513$	.487
25	$25 - \sqrt{24}\sqrt{25}$	$= .506$	.494
100	$100 - \sqrt{99}\sqrt{100}$	$= .502$	.498
500	$500 - \sqrt{499}\sqrt{500}$	$= .500$	.500

shrinks to the competitive equilibrium solution, i.e., $r = .5$. Moreover, the shrinking is "fast." With only three pairs of landowners and tenants, the core consists of those solutions which are within approximately 10% of $r = .5$. More generally, for a production function of the form

$$Q = H^{\alpha}L^{(1-\alpha)},$$
$$r_{max} = n - (n - 1)^{\alpha}n^{(1-\alpha)},$$
$$r_{min} = 1 - r_{max},$$

and r_{max} and r_{min} converge to α as n becomes large.[7]

Behavior of the Core with More Tenants Than Landowners

Assume now that there are always twice as many tenants as landowners. In order to focus on the effect of this assumption on the bargaining solution, we assume that each tenant is endowed with $\frac{1}{2}$ of a unit of labor. This suffices to keep the land-labor ratio equal to 1 for all core solutions, just as it was for the economy investigated above.

Beginning with an economy with one landowner and two tenants, $r_{max} = 1$ because $RBC_{0,2}$ has no land. Then r_{min} is determined relative to $RBC_{1,1}$ and satisfies

$$1^{\frac{1}{2}}(\tfrac{1}{2})^{\frac{1}{2}} - r = \frac{(1 - r)}{2},$$

$$\text{i.e., } r_{min} = \frac{2}{\sqrt{2}} - 1 = .415.$$

Again proceeding by induction, the limits of the core for the general case of n landowners and $2n$ tenants are

Table 2. Core Shrinking with Twice as Many Tenants as Landowners

n (number of landowners)	r_{max}	r_{min}
1	1.000	.414
2	.586	.464
5	.528	.486
10	.513	.492
50	.503	.497
500	.500	.500

$$r_{max} = n - (n - 1)^{\frac{1}{2}}n^{\frac{1}{2}} \text{ and}$$
$$r_{min} = 2n^{\frac{1}{2}}(n - \tfrac{1}{2})^{\frac{1}{2}} - 2n + 1.^{8}$$

The limits of the core for various values of n are given in table 2. Notice that the r_{max} column in table 2 is identical to that in table 1. This is because the RBC with $n - 1$ landowners and $2n$ tenants, each with $\frac{1}{2}$ unit of labor, is indistinguishable from the RBC (from case one) of $n - 1$ landowners and n tenants, each with 1 unit of labor. On the other hand, r_{min} is no longer symmetrical to r_{max}. With twice as many tenants as landowners, it is now more difficult for tenants to "exploit" landowners. Landowners can minimize exploitation by forming a blocking coalition with all but one tenant. This involves sacrificing the marginal product of only $\frac{1}{2}$ of a labor unit as compared to 1 unit in the "symmetric" case.

Limiting our attention to economies where the number of landowners does not exceed the number of tenants, we can now draw the following conclusions from these and similar exercises. First, the core shrinks rapidly to the Walrasian equilibrium regardless of the ratio of tenants to landowners. Second, for a production function of the form $Q = H^{\alpha}L^{(1-\alpha)}$, r_{max} converges to α, the rate of convergence being independent of the tenant-landowner ratio.[9] Third, $r_{max} \geq r_{min} \geq 1 - r_{max}$, i.e., r_{min} converges to α (from below) at least as fast as r_{max} approaches α (from above).

[7] This convergence is readily checked by substituting any number between 0 and 1 for α.

[8] For an economy with 2 landowners and 4 tenants, r_{max} is determined by (from $RBC_{1,4}$),

$$1^{\frac{1}{2}}\left(\frac{4}{2}\right)^{\frac{1}{2}} - \frac{4(1 - r)}{2} = r, \text{ i.e.,}$$

$$r_{max} = 2 - \sqrt{2} = .586.$$

r_{min} is determined relative to $RBC_{2,3}$ and is given by

$$2^{\frac{1}{2}}\left(\frac{3}{2}\right)^{\frac{1}{2}} - \frac{3(1 - r)}{2} = 2r, \text{ i.e.,}$$

$$r_{min} = .464.$$

[9] This is readily confirmed by substituting other values for α, besides $\alpha = \frac{1}{2}$ or by substituting α and $1 - \alpha$ in the general expression for r_{max} taking the limit as $n \to \infty$.

These results provide a justification for the assumption of contract-term-taking behavior on the part of the landowners and tenants. Despite the assumption that landowners and tenants are free to bargain with one another about possible deviations from the equilibrium set of contracts, no such changes are viable in the sense of making all of the recontracting parties better-off. Thus, Cheung's (1969) intuition, that the power of individual landowners to establish inefficient exploitative contracts is limited by competition among landowners, can be shown to be formally correct. Furthermore, it has been established that for the competition to be effective, the minimum number of landowners (with at least as many tenants) is relatively small.

Specific Production Externalities and the Coase Theorem

Coase has been credited with the insight that externalities, i.e., nonmarket interdependencies among agents, are not a sufficient condition for inefficiency. Private negotiation may suffice to "internalize" the externality. More specifically, Coase asserted that if transactions costs are zero, private negotiation will remove the externality. This simple idea has been extracted from his article—a profound and pioneering treatise on law and economics—and labeled "the Coase theorem."

There has been an extensive debate in the economics literature regarding the proper statement of the Coase theorem and whether or not various versions are correct. The following is a fairly accurate synthesis of the many versions of the theorem:

If costless negotiation is possible, rights are well-specified, and redistribution does not affect marginal values, then

a. *The allocation* [*sic*] *of resources will be identical, whatever the allocation of legal rights.*
b. *The allocation will be efficient so there is no problem of externality.* (Layard and Walters, p. 192).

As Arrow notes, the second part of the theorem can only be proven by assuming that the only admissible solution concepts for cooperative games are those which are Pareto optimal by definition. That is, since the conclusion must be stated in the premise, the proposition is trivial.

The corollary stated above, however, provides a nontrivial version of Coase's proposition. If contracts serve as perfect substitutes for markets, it is irrelevant for resource allocation and income distribution if some markets do not exist, i.e., that certain interagent effects are external to markets. An allocation identical to that of the Walrasian equilibrium with universal markets will obtain regardless. In the pollution case, for example, the universal market solution includes a market in "polluter's rights" with a corresponding parametric price (Dales). Such a market is unnecessary, however, since private contracting among polluters and pollutees will achieve the same result.

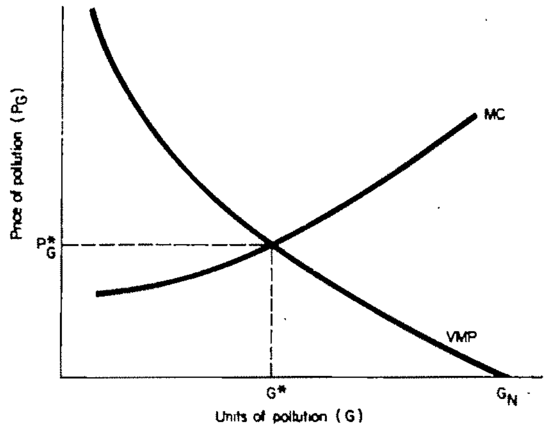


Figure 1. The Lindahl pollution solution

For purposes of illustration, consider the case of Upton's paper mill which dumps waste into a river which is used by Downley Baths (Starrett and Zeckhauser). The universal market solution for this example is depicted in figure 1. The graph shows the value of the marginal product, *VMP*, (to Upton) of the right to dump *G* units of "garbage" in the river and the minimum marginal cost, *MC*, to Downley of successive units dumped. In the case of pollutee rights, the universal market solution involves Upton buying G^* "pollution rights" (Dales) from Downley at the equilibrium price, P^*_G. This is equivalent to imposing a Pigouvian tax, $t = P^*_G$, on Upton per unit of G discharged and giving the proceeds to Downley on the basis of the minimum marginal cost (i.e., Downley is compensated according to the marginal cost he would incur if he invested optimally in pollution avoidance activities such as water filters).[10] Both the

[10] Since the compensation is not tied to Downley's actual behavior, it does not cause Downley to underinvest in avoidance activities as Baumol claims.

market and tax solutions are also equivalent to the competitive contract solution wherein Upton pays Downley $P^*_G G^*$ for the right to dump G^*.

There is a different set of equivalent solutions under polluter rights. For the universal market solution, polluter rights may be represented by initially endowing Upton with G_N pollution rights. In market equilibrium, Upton sells $G_N - G^*$ rights to Downley at price P^*_G. This is equivalent to Downley paying Upton a Pigouvian subsidy, $s = P^*_G$, for each unit that Upton reduces G below the profit-maximizing level, G_N. It is also equivalent to the contracting solution wherein Downley pays Upton $P^*_G(G_N - G^*)$ to reduce pollution to G^*.

In general, the core shrinks to a different universal market solution for each specification of property rights.[11] If we assume that changing property rights "does not affect marginal values" (the Layard and Walters version of the Coase theorem) then the production of the externality is independent of property rights. We have implicitly followed this assumption, to simplify the exposition, in our discussion of figure 1. Typically, however, marginal values will be affected, via both income effects and changes in relative factor prices. In the long run, we normally would expect a shift to polluter rights to be associated with an increase in pollution, although the amount of the change may be small.

As usually presented, the Coase solution holds the equilibrium quantity to be uniquely determined but the division of surplus between contracting parties to be indeterminate. Thus, the unaffected-marginal-values assumption is necessary to prevent an inconsistency. This assumption becomes unnecessary in the revised Coase theorem, because both quantities and income distribution are determined.

It is natural to question the applicability of the competitive contracting solution to most of Coase's examples which involve only two parties. For example, we envision one rancher's cattle affecting one farmer's crops. Similarly, in the case of *Sturges* v. *Bridgman* there was one confectioner bothering one (neighboring) doctor. But, our corollary requires a sufficient number of agents to make bargaining power small on both sides. As Coase has noted in verbal discussions of his paper, however, it is competition prior to the contract that counts. That is, even for one-to-one externalities there is *ex ante* competition in the sense that the parties involved can choose among various locations, and several parties may be competing for a particular location (Demsetz, in a personal communication).

One advantage in appealing to the Debreu-Scarf theorem as a cornerstone of the theory of contracts is that we have a list of sufficient postulates under which the theorem is valid. This gives us clues about when competitive contract theory is and is not applicable. In particular, it has been shown that the core of an economy with a public good does not shrink as the number of consumers is increased (Bergstrom 1970, and Muench). As the number of consumers increase, "agreers' surplus" (Pauly) increases because each successive consumer adds to total benefits of the public good without increasing its costs. As the surplus per member increases so does the range of viable solutions, i.e., the core "grows." In other words, because all members of the community are needed as members of the coalition which consumes the public good in order to minimize its average cost, there are no viable competing coalitions which can provide the competition required to make the core "shrink." Thus, the core of an economy with a public good contains a large number of solutions, each with its own prescription for sharing the surplus generated by group provision of the public good. Thus, in an economy with public goods we cannot say contracts necessarily tend to act as perfect substitutes for universal markets.

Similarly, the core does not shrink in the case of joint externalities. For example, if one agent contributes to a "pool" of pollution which negatively affects several recipients, then the pollution is a public bad for that community of recipients. Thus, the limit theorem can only be applied to specific, i.e., one-to-one, externalities. A classic example of a specific production externality is the case where a particular bee (or unit of bees) provides pollinating services during a particular unit of time to a particular apple orchard. As Cheung (1973) has shown, a contracting solution does in fact exist between beekeepers and apple orchard owners in the state of Washington which approximates a competitive market solution. Coase's examples were also specific production externalities. Even in the case of

[11] This result appears to be inconsistent with an example provided by Starrett wherein the core does not contain the Lindahl equilibrium (universal market solution). The paradox is resolved by noting that Starrett implicitly compares the core under polluter rights with the Lindahl equilibrium under pollutee rights.

the railroad whose sparks caused fires on adjacent farmers' fields, one unit of spark affects only one farmer. Thus, for the examples Coase had in mind the competitive theory of contracts serves as a correct and nontrivial version of Coase's proposition.

Another limitation of the theory regards restrictions on production. The Debreu-Scarf theorem requires that the production possibility correspondence is additive (Hildenbrand, p. 212). Additivity is satisfied by constant returns-to-scale. If economies of scale prevail, then it is possible that the Walrasian equilibrium does not exist and that the core is empty (Arrow). If decreasing returns prevail, then the core may contain allocations besides the Walrasian equilibria, regardless of the number of agents (Böhm).

Because a Walrasian equilibrium with universal markets is also called a Lindahl equilibrium (Bergstrom, 1975, 1976), we can now summarize as follows:

> The core of an economy with additivity in production, but no joint externalities, shrinks to the Lindahl equilibrium as the bargaining power of all agents is reduced by increasing numbers of agents.

Conclusions and Applications

Abstracting from transactions costs and bargaining power, the equilibrium contracting solution is just the Walrasian equilibrium with universal markets. This cornerstone of contract theory helps to clear up some controversies about sharecropping and production externalities.

Applying the proposition to sharecropping, we get Cheung's (1969) competitive theory of share tenancy. But instead of relying on the assumption that agents are "contract-term-takers" (e.g., as in Reid), the proof involves showing that the core shrinks to the Walrasian equilibrium. In the process of this demonstration, we learn that the core shrinks "fast," i.e., that even for a few landowners, solutions which deviate substantially from the Walrasian equilibrium are not viable.

Applying the proposition to production externalities, we see that the competitive theory of contracts serves as a revised version of, or a substitute for, the Coase theorem. That is, under zero transaction costs and where the production externality situation is characterized by precontract competition, the contracting solution is identical to the market solution where a market exists for the externality good. Furthermore, for any given specification of property rights, the contracting solution is identical to the universal market solution (Lindahl equilibrium) and is also equivalent to a Pigouvian solution. Thus, the efficiency of the contracting solution, the Pigouvian solution, and the market solution cannot be compared on "first-best" grounds as several authors (e.g., Baumol) tried to do. As Coase has said, in a personal communication, "the real choice in economic policy is a choice of institutional forms," and a complete evaluation inevitably requires considerations of transactions costs and excess burdens of alternative arrangements.

For positive analysis, however, even the simple theory of competitive contracts may be sufficient to explain some of the stylized facts of economic organization. For example, by combining the theory with reasonable specifications about land quality and production technology, we are able to explain the observation for share contracts that the landowner's percentage share tends to be positively related to land quality and physiological population density.[12] On the other hand, many of the rich variations of real world contracts will require a theory which incorporates transactions costs and bargaining power into the explanatory framework (see Roumasset 1978).

[*Received May 1978; revision accepted April 1979.*]

References

Arrow, K. J. "The Organization of Economic Activity: Issues Pertinent to the Choice of Market versus Non-market Allocation." *The Analysis and Evaluation of Public Expenditures: The PPB System*, pp. 46–64. Washington, D.C.: U.S. Congress, Joint Economic Committee, 1969.

Aumann, R. J. "Markets with a Continuum of Traders." *Econometrica* 32(1964):39–50.

Bardhan, P. K., and T. N. Srinivasan. "Cropsharing Tenancy in Agriculture: A Theoretical and Empirical Analysis." *Amer. Econ. Rev.* 61(1971):48–64.

Baumol, W. "On Taxation and the Control of Externalities." *Amer. Econ. Rev.* 42(1972):307–22.

Bergstrom, T. "Collective Choice and the Lindahl Allocation Method." Mimeographed. Washington University, St. Louis, MO., 1970.

———. "The Core When Strategies Are Restricted by Law." *Rev. Econ. Stud.* 42(1975):249–57.

[12] The explanatory models used combine the first-best theory of contracts with reasonable and testable restrictions about the underlying production functions.

———. "Regulation of Externalities." *J. Public Econ.* 5(1976):131–38.

Böhm, V. "On Cores and Equilibria of Productive Economies with a Measure Space of Consumers: An Example." *J. Econ. Theory* 6(1975):409–12.

Cheung, S.N.S. *The Theory of Share Tenancy*. Chicago: University of Chicago Press, 1969.

———. "The Fable of the Bees: An Economic Investigation." *J. Law and Econ.* 7(1973):11–33.

Coase, R. H. "The Problem of Social Cost." *J. Law and Econ.* 3(1969):1–44.

Dales, J. H. *Pollution, Property and Rights*. Toronto: University of Toronto Press, 1968.

Debreu, G., and H. Scarf. "A Limit Theorem on the Core of an Economy." *Int. Econ. Rev.* 4(1963):235–46.

———. "The Limit of the Core of an Economy." *Decision and Organization*, eds. C. B. McGuire and R. Radner. Amsterdam: North-Holland Publishing Co., 1972.

Edgeworth, F. Y. *Mathematical Psychics: An Essay on the Application of Mathematics to the Moral Sciences*. London: P. Kegan, 1881.

Hildenbrand, W. *Core and Equilibria of a Large Economy*. Princeton, N.J.: Princeton University Press, 1974.

Johansen, L. "A Calculus Approach to the Theory of the Core of an Exchange Economy." *Amer. Econ. Rev.* 68(1978):813–20.

Layard, P. R. G., and A. A. Walters. *Microeconomic Theory*. New York: McGraw-Hill Book Co., 1978.

Muench, T. "The Core and the Lindahl Equilibrium of an Economy with a Public Good: An Example." *J. Econ. Theory* 4(1972):241–55.

Pauly, M. V. "Clubs, Commonality, and the Core: An Integration of Game Theory and the Theory of Public Goods." *Economica* NS(1967):314–24.

Reid, J. D., Jr. "Sharecropping and Agricultural Uncertainty." *Econ. Develop. and Cultur. Change* 24 (1976):549–76.

Roberts, D. J. "The Lindahl Solution for Economies with Public Goods." *J. Public Econ.* 3(1974):23–42.

Roumasset, J. A. "The New Institutional Economics and Agricultural Organization." *Philippine Econ. J.* 17(1978):xxx–xxx.

Roumasset, J. A., and W. James. "Explaining Variations in Share Contracts: Land Quality, Population Pressure and Technological Change." *Aust. J. Agr.* forthcoming.

Shubik, M. "Edgeworth Market Games." *Contributions to the Theory of Games, IV, Annuals of Mathematical Studies*, eds. R. D. Luce and A. W. Tucker, pp. 267–78. Princeton, N.J., Princeton University Press, 1959.

Starrett, D. "A Note on Externalities and the Core." *Econometrica* 41(1973):179–83.

Starrett, D., and R. Zeckhauser. "Treating External Diseconomies—Markets or Taxes." *Statistical and Mathematical Aspects of Pollution Problems*, ed. J. W. Pratt. New York: Dekker, 1974.

Weintraub, S. *Modern Economic Thought*. Philadelphia: University of Pennsylvania Press, 1977.

Long-Term Marketing Contracts: Intra-Firm Optima and Inter-Firm Agreement

S. T. Buccola and B. C. French

Long-term marketing contracts may be used to control risks associated with sales or purchase quantities, prices, or other trade terms. A model is here specified through which a firm may select portfolios of contract price clauses that maximize its expected utility. Offer curves are defined relating optimal portfolios to contract price parameter levels, and an equilibrium trade solution is developed among three vertically related agribusiness concerns. Price clauses considered for analysis—market price, cost-plus, and sales-minus—may be optimally utilized together, but only in restricted price parameter and utility function ranges.

Key words: cooperative, cost-plus, expected utility, marketing contracts, utility analysis.

The pervasive demand for opportunities to reduce risk, together with recent accentuation of market risks caused by declining firm numbers, product specialization, and capital intensification, have led to increasing use of marketing contracts in U.S. agribusiness. Contract clauses generally are distinguished according to sources of risk that can be controlled. Some of these are necessary elements of an act of trade: price and method of payment, shipment volume and timing, place of title transfer, and product specification and quality. Others serve to clarify trade terms or promote the contract's implementation: dockages and premiums, finance arrangements, technical services, clause flexibilities, and redress for noncompliance (Jesse and Johnson).

There is a bewildering variety of ways in which each contract clause can be formulated. Price formulas include fixed price, market price, and cost-plus, to name a few. Quantities can be fixed or follow time- or inventory-related formulas. Both price and quantity can be related to product quality (Harris and Massey). Past contract literature generally has employed an efficiency framework in which mean-variance trade-offs are calculated for alternative contract formulas or portfolios. Most models focus on fixed prices versus cash or futures market prices. Market contract terms are usually a single year and assume the firm has no influence over specification of the alternative formulas (Eidman, Dean and Carter; Barry and Willmann).

The goal of the present paper is to expand the portfolio analysis of contracting to encompass long-term contract decisions, additional pricing possibilities, and optimal marketing plans. Most important, it addresses a problem in which neither seller nor buyer is a price taker, and in which both the proportions of trade allocated to alternative formulas and the formulas themselves are decided through negotiation. A method for determining these equilibrium trade terms is proposed which may assist firms and government advisors in understanding and influencing the contract negotiation process.

The study considers a U.S. fruit- and vegetable-processing cooperative, a contracting customer for its bulk-packed tomato paste, and contracting nonmember suppliers of raw tomatoes. Following sections define the research problems in more exact terms, prescribe individual firm and joint market solu-

Steven T. Buccola is assistant professor of agricultural economics, Virginia Polytechnic Institute and State University; Ben C. French is professor of agricultural economics, University of California, Davis.

This research project was financed by a grant from the Farmer Cooperative Service, (now Economics, Statistics, and Cooperatives Service) U.S. Department of Agriculture.

The authors acknowledge the help of two *Journal* reviewers in preparation of the report.

tions, then report model construction and results based on these prescriptions.

The Contract Portfolio Problem

In a stochastic universe and over a defined time horizon, a firm designing its marketing mix may be thought to prefer the set of contract formulas and open market opportunities that maximize the expected utility of present value profit. In a specific application of this problem addressed here, each firm holds a fixed quantity Q^o of one kind of output, and q^o of a principal input, and allocates these amounts among fixed-quantity sales and/or fixed-quantity purchase contracts that differ in pricing provisions. Defining P_a, Q_a as price and quantity of output sold under contract provisions a, $a = 1, \ldots, A$; P_b, q_b, price and quantity of input purchased under contract provisions b, $b = 1, \ldots, B$; $V_a = Q_a/Q^o$, sales portfolio proportions, $a = 1, 2, \ldots, A$; $R_b = q_b/q^0$, purchase portfolio proportions, $b = 1, 2, \ldots, B$; OR_t, OC_t, revenues and costs, respectively, associated with noncontracted items; t, a time period indicator, $t = 1, 2, \ldots T$; i, an average interest rate; and δ_1, δ_2, constants ($0 \leq \delta_1, \delta_2 \leq 1$), the expected-utility maximization problem becomes

$$\max_{V,R} E\left[U\left(\sum_a \sum_t \frac{1}{(1+i)^t} P_{at} V_a Q^o - \sum_b \sum_t \frac{1}{(1+i)^t} P_{bt} R_b q^o + \sum_t \frac{1}{(1+i)^t} (OR_t - OC_t)\right)\right]$$

$$\text{(1)} \qquad \text{s.t.} \sum_a V_a = \delta_1$$

$$\sum_b R_b = \delta_2$$

$$V_a, R_b \geq 0, \quad \text{all} \quad a, b.$$

This form becomes more determinate once traded commodities, market conditions, and alternative contract price formulas are specified. The authors are concerned with a multicommodity processing/marketing cooperative that contemplates contract paste sales to one buyer only. The buyer in turn reprocesses the paste into a line of tomato sauces and distributes it to retail markets. Some coop tomato requirements are purchased on a nonmembership contract basis from growers who also supply tomatoes on a membership basis. Firms at all three levels buy and sell additional goods in noncontractual markets, where they are price takers. The cooperative has agreed with the distributor/reprocessor on the total paste tonnage it will sell to it for the next ten years, and with growers on the number of nonmembership and membership acres whose yield it will purchase for the same period.

Price mechanisms considered suitable for either tomato paste sales or nonmember raw tomato purchases are (a) a specifically defined market price, (b) the seller's variable costs times a markup ("cost-plus"), and (c) the buyer's revenue from product resale times a markdown ("sales-minus"). Under market price contracts, both traders may avoid terms less advantageous in a short-run sense than those offered on the open market. Cost-plus prices provide sellers a guaranteed rate of gross margin, and sales-minus prices guarantee buyers a rate of return over the contracted input.

Profit Functions

In order to incorporate these specifications into a set of operational profit functions, we define the following symbols: (a) W_a, V_a, R_b, S_b ($a,b = 1, 2, 3$) are portfolio proportions of trade assigned, respectively, to the distributor's alternative paste purchase price formulas, cooperative's paste sales price formulas, cooperative's tomato purchase price formulas, and growers' nonmember tomato sales price formulas. (In each case, 1 is market price, 2 is cost-plus, 3 is sales-minus.)

(b) Q_d, Q_c, A_c, A_g are fixed total trade levels representing, respectively, the distributor's total contractual paste purchase from the cooperative (in tons raw equivalent); the cooperative's total contractual paste sales to the distributor (in tons raw equivalent); the cooperative's total contractual nonmember tomato purchases from growers (in acres); and growers' total contractual nonmember tomato sales to the cooperative (in acres). ($Q_d = Q_c = \alpha\beta A_c = \alpha\beta A_g$, where α is expected per acre tomato yields, and β is the proportion of total

cooperative tomato acres contracted on a nonmembership basis.)[1]

(*c*) m, k, n, l are contract price parameters, where $m, k > 1$ are cost-plus markups and n, l ($0 \leq n, l \leq 1$) are sales-minus markdowns.

(*d*) $MP_{sce}{}^{tr}$, $MP_{pst}{}^{tr}$, $MP_{tom}{}^{tr}$ are market prices of sauce, paste, and tomatoes per ton raw product equivalent; and $Y_{tom}{}^{a}$ is per acre tomato yield.

(*e*) $NPVC_{sce}{}^{tr}$ is nonpaste variable cost of sauce production per ton raw equivalent, $NTVC_{pst}{}^{tr}$ is nontomato variable cost of paste production per ton raw equivalent, and $VCG_{tom}{}^{a}$ is variable cost of tomato production per acre.

(*f*) $REVC$ is cooperative revenue from contract paste sales divided by A_c.

(*g*) ORD, ORC, ORG are other revenues; FCD, FCC, FCG are fixed costs; and $OVCD$, $OVCC$, $OVCG$ are other variable costs of the three firms.

Variables in (*d*) through (*g*) are, with the exception of fixed costs, considered random. Those which serve as coefficients of portfolio proportions W, V, R, S will be termed contract price bases. The definitions permit us to define profit or net margin functions for distributor/reprocessor, cooperative, and growers which reflect the trade arrangements and alternative price mechanisms discussed above:

Distributor

$$(2) \quad \pi_d = ORD + Q_d(MP_{sce}{}^{tr} - NPVC_{sce}{}^{tr}) - Q_d[W_1 MP_{pst}{}^{tr} + W_2 m(MP_{tom}{}^{tr} + NTVC_{pst}{}^{tr}) + W_3 n MP_{sce}{}^{tr}] - OVCD - FCD;$$

Cooperative

$$(3) \quad NM_c = ORC + Q_c[V_1 MP_{pst}{}^{tr} + V_2 m(MP_{tom}{}^{tr} + NTVC_{pst}{}^{tr}) + V_3 n \cdot MP_{sce}{}^{tr}] - A_c[R_1 MP_{tom}{}^{tr} Y_{tom}{}^{a} + R_2 k VCG_{tom}{}^{a} + R_3 l REVC] - Q_c[NTVC_{pst}{}^{tr}] - OVCC - FCC;$$

Grower (Nonmember Basis)

$$(4) \quad \pi_g = ORG + A_g[S_1 MP_{tom}{}^{tr} Y_{tom}{}^{a} + S_2 k VCG_{tom}{}^{a} + S_3 l REVC] - A_g[VCG_{tom}{}^{a}] - OVCG - FCG.$$

Following the approach taken by Helmberger and Hoos (p. 604), and adapted to multiproduct situations by Hardie (pp. 820–21), cooperative net margin (3) does not value member raw product as a cost. Members instead have a claim on total net margin in proportion to the tonnage, or market value, of all raw products delivered to the coop on a membership basis (Ladd, p. 511, eq. 5, adopts the same approach in his analysis of bargaining cooperatives, except that in his case the coop is also assumed to provide members with a set of input services, his S_1 and S_2.)

In addition to noncontractual revenue sources (ORC), cooperative revenue, of (3), consists of paste tonnage sold to the distributor times: a proportion V_1 of the market value per ton of paste (market price); a proportion V_2 of paste production variable costs per ton, times a coop rate of return m (cost-plus); and a proportion V_3 of distributor sales revenue from sauce produced with the coop's tomato paste, times the coop's revenue share n (sales-minus). Cooperative nonmember tomato acquisition cost, lines 3, 4 in (3), consists of nonmember tomato acreage times: a proportion R_1 of the market value of an acre's tomato yield (market price); a proportion R_2 of tomato production variable costs per acre, times a grower rate of return k (cost-plus); and a proportion R_3 of cooperative per acre sales revenue from paste produced with nonmember tomatoes, times the grower's per acre revenue share l (sales-minus). Elements in lines 5, 6 of (3) are nontomato paste production costs, and other cooperative variable and fixed costs.

Profit functions for distributor and grower are interpreted similarly. Note that market price, cost-plus and sales-minus paste purchase formulas in the third expression of (2) are, with due allowance for differences in proportion terms, identical to the paste sales formulas in the second expression of (3). In addition market price, cost-plus, and sales-minus nonmembership tomato purchase formulas in the third expression of (3) are, except for proportion terms, identical to the nonmembership tomato sales formulas in the second expression of (4). Random variables in (2) through (4) are present values of ten-year sums as required by the time summation in (1).

Model Construction: Contract Offer Curves

Price parameters m, n, k, l and portfolio proportions W, V, R, S in (2)–(4) may be consid-

[1] Presence of random yields implies tomato purchases may not exactly meet the coop's commitments to sell a fixed tonnage of paste. Although such discrepancies are in reality handled through inventory adjustments or changes in extracontractual arrangements, neither of these adjustments are included in the present model. In this sense, the model may understate risk exposure. However yield uncertainties themselves are included in profit probability distributions of each contractual arrangement.

ered constants in formulas defining the respective moments μ_π, σ_π^2, . . . , $E(\pi - \mu_\pi)^n$ of profit or net margin for each firm. Substituting these moment expressions into expectations of the Taylor expansion of each firm's utility-for-profit generates expected utility expressions as functions of the price parameters and portfolio proportions (Anderson, Dillon, Hardaker, p. 97). In general notation,

$$
\begin{aligned}
(5)\quad E[U_d(\pi_d)] &= g_1(W_1, W_2, W_3; m, n)\\
E[U_c(NM_c)] &= g_2(V_1, V_2, V_3, R_1, R_2, R_3;\\
&\qquad m, n, k, l)\\
E[U_g(\pi_g)] &= g_3(S_1, S_2, S_3; k, l),
\end{aligned}
$$

where E is an expectation operator; U_d, U_c, U_g are utilities; and g_1, g_2, g_3 are function indicators. For any set of mean, variance, covariance and higher moment estimates for the price bases, and for any set of price parameters m, n, k, l, portfolio proportions W, V, R, S may be found which maximize private expected utilities (5). By computing the first partial derivatives of (5) with respect to each portfolio proportion, setting these equal to zero, and simultaneously solving the equations for the unknown proportions, an expected-utility-optimal surface is produced in which each portfolio proportion is a function of all parameters present:

(6) Distributor:

$$W_a = W_a(m, n) \qquad a = 1, 2, 3$$

Cooperative:

$$V_a = V_a(m, n, k, l) \quad a = 1, 2, 3$$
$$R_b = R_b(m, n, k, l) \quad b = 1, 2, 3$$

Grower:

$$S_b = S_b(k, l) \qquad b = 1, 2, 3.$$

In this derivation the constraint that portfolio proportions sum to a constant—δ_1 or δ_2 in (1)—may be incorporated by expressing, in the distributor problem for example, $W_3 = \delta_1 - W_1 - W_2$. "Border solutions" are special cases of (6) that occur when one of these portfolio proportions is at zero level.

Equations (6) represent the firms' offer curves for market price, cost-plus, and sales-minus contract formulas. W and V functions are demand and supply, respectively, in the paste market. R and S functions are demand and supply, respectively, in the raw tomato market. An equilibrium solution for all price parameters and portfolios in both markets is suggested by combining (6) with market clearing equalities $W_2 = V_2$, $W_3 = V_3$, $R_2 = S_2$, $R_3 = S_3$. Solutions for $W_1 = V_1$, $R_1 = S_1$ are subsequently derived from proportionality constraints $\sum_a W_a = \sum_a V_a = \delta_1$, $\sum_b R_b = \sum_b S_b = \delta_2$, as in (1). An unrestricted equilibrium solution exists for the sixteen unknowns in (6) if the equations are independent and if offer curves for each contract option intersect in the nonnegative price-quantity quadrant. The independence requirement is met because each offer curve represents a different trade or contract option. Intersection in the nonnegative quadrant is not guaranteed; in the event a negative portfolio proportion W, V, R, S is indicated for any pair of traders, true equilibrium occurs where the proportion allocated to one option is 100% and the rest zero.

The contract problem in this framework may be envisaged as a sequential process. Each negotiator first assigns personally suitable values to cost-plus markups m, k and sales-minus markdowns n, l, then decides which proportions of the several price formulas maximize expected utility, given these constants. If buyer's and seller's resultant quantity offers under each formula are inconsistent, markups and markdowns are adjusted and the process repeated with the hope that consistency will be achieved.

Supply and demand curves (6) are, like those in neoclassical theory, nonstochastic. In the tradition of neoclassical analysis, two contract formulas are defined as substitutes when the portfolio proportion occupied by one rises as the other falls, and as complements when they rise and fall together. Own-price effects are partial derivatives relating the influence of a price parameter on its associated portfolio proportion, and cross-price affects the influence of a price parameter on an unassociated portfolio proportion. In the distributor's case, for example, own effects are $\partial W_2/\partial m$, $\partial W_3/\partial n$. Cross-effects are $\partial W_1/\partial m$, $\partial W_1/\partial n$, $\partial W_2/\partial n$, $\partial W_3/\partial m$. Market price options only have cross-effects since they employ no price parameters (premium or discount factors) in this model.

Parameters Employed

Complete specification of expected utility functions (5) requires selection of a functional form for each firm's utility of profit. If the firms' utility functions are quadratic in profit and if profit functions (2)–(4) are linear in portfolio proportions W, V, R, S, expected utility functions (5) are quadratic in these port-

folio proportions (Anderson, Dillon, Hardaker, pp. 97–98). In the cooperative's case, for example,

$$(7)\quad E[U_c(NM_c)] = a\mu_\pi - b(\mu_\pi^2 + \sigma_\pi^2),$$

where

$$(8)\quad \begin{aligned} \mu_\pi &= \mu_\pi(V, R; m, n, k, l) \\ \sigma_\pi^2 &= \sigma_\pi^2(V, R; m, n, k, l), \end{aligned}$$

and constants a, $b > 0$ are the linear and quadratic terms, respectively, of the utility-of-profit function. Results reported here assume quadratic utilities and linear profit functions for all firms.[2]

Profit-utility responses were elicited by the Von Neumann-Morgenstern (pp. 15–31) technique for eight tomato growers and for spokesmen from cooperative management and board. Utilities of the board spokesman and one grower were linear; all others were slightly to strongly risk-averse. Because no cooperation was obtained from an important customer of the cooperative's tomato paste, a hypothetical utility had to be used in conjunction with the distributor model.

[Quadratic functions employed are $U = 3.098\pi - .0469\pi^2$ (grower); $U = .031\pi - .000006\pi^2$ (cooperative); $U = .01\pi - .0000015\pi^2$ (distributor), where profit π is expressed in \$10,000 units.]

Once functions (8) were derived for each firm from profit functions (2)–(4), it was necessary to (*a*) develop mean and variance estimates for each revenue and cost variable and covariance estimates for each pair of these variables; (*b*) specify fixed total trade levels Q_d, Q_c, A_c, A_g; and (*c*) substitute into (8) provisional contract-price parameter values m, n, k, and l.

Mean and variance estimates for each revenue, price, cost, and yield term, defined over a ten-year planning horizon, were developed through a simulation program described in Buccola and French. This program incorporated historical data with subjective probability distributions elicited from decision makers. Where appropriate, revenue and cost moments were calculated from price and yield moments by use of standard formulas for product moments (Kmenta, pp. 57–66). Correlation coefficients were computed from historical series.

The distributor was assumed to contract with the cooperative for purchase of 75,800 tons of 32% tomato paste [in (2) and (3), raw product equivalents $Q_d = Q_c = 473{,}219$]. The cooperative, in turn, contracted to purchase the tomato output of 18,860 acres, of which 25% or 4,715 acres were allocated to nonmembers ($A_c = 4{,}715$). A representative grower raised 1,210 acres of tomatoes and an additional 1,940 acres of corn, wheat, and beans in a 5:3:2 proportion. Twenty-five percent, or 302, of the grower's tomato acres were sold to the coop on a nonmember basis [in (4), $A_g = 302$] and the remainder on a member basis. In this context the equilibration task was to discover values of price parameters m, n, k, l which would allocate the 75,800 tons of paste to a set of sales methods mutually acceptable to cooperative and distributor, and simultaneously allocate the 4,715 acres of tomatoes among sales methods mutually acceptable to the cooperative and a representative grower.

Model Results

Table 1 presents purchase and sale contract portfolios that maximize the cooperative's expected utility, given a particular set of contract price-basis probability moments, one cooperative executive's utility function, and selected values of the contract price parameters. (Similar tables for distributor and representative grower are omitted due to space considerations.) Offer curves for each contract option were estimated by regressing the portfolio proportions occupied by that option against all relevant price parameters. It was important that each firm's optimal portfolios be segregated into "interior" and "boundary" solution groups before such estimation. Due to the portfolio proportion nonnegativity conditions, offer curves develop a kink when any proportion reaches zero level. Hence linear fits to unsegregated data represent misleading averages of truly piecewise offer functions. In the cooperative paste sale model, for example, an interior solution occurs where $0 < V_1, V_2, V_3 < 1$. Six types of boundary solutions occur where $V_1 = 0, 0 < V_2, V_3 < 1$; $V_2 = 0, 0 < V_1, V_3 < 1$; $V_3 = 0, 0 < V_1, V_2 < 1$; $V_1 = 1$; $V_2 = 1$;

[2] Profit linearity restricts the accuracy with which some price options can be modeled. For example the cooperative sales-minus purchase option theoretically requires substituting the entire cooperative revenue expression into *REVC* in (3). Because the result is a quadratic expression, it is assumed that all paste is sold at market prices for the purpose of this option. Thus $REVC = MP_{pst}{}^{tr}Y_{tom}{}^{c}$.

Table 1. Optimal Contract Portfolios for Cooperative Tomato Paste Sales under Selected Price Parameters

Sales Contract Price Parameters		Sales Contract Proportions		
Cost-Plus Markup (m)	Sales-Minus Markdown (n)	Market Price (V_1)	Cost-Plus (V_2)	Sales-Minus (V_3)
1.39	.248	.268	.697	.035
1.39	.250	.173	.582	.245
1.39	.252	.064	.468	.468
1.38	.248	.375	.511	.113
1.38	.250	.270	.387	.344
1.38	.252	.150	.278	.572
1.38	.254	.034	.203	.763
1.37	.248	.473	.309	.218
1.37	.250	.356	.188	.456
1.37	.252	.226	.098	.676
1.36	.246	.655	.242	.103
1.36	.248	.552	.111	.338

Note: Purchase-side parameters $k = 1.35$ and $l = .38$; all tomato purchases are at sales-minus. $U = .031\pi - .000006\pi^2$ (π in \$10,000 units). Total paste volume sold is 75,800 tons.

and $V_3 = 1$. Only interior solutions are shown in table 1.

Linear offer curve sets for each firm, estimated from interior solution data in table 1 and the omitted tables, are shown in table 2. Cooperative tomato purchase portfolios were so sensitive to price parameter changes that interior solutions for them were not obtainable. A brief discussion follows of each offer curve set in table 2.

Table 2. Interior-Solution Offer Curves for Distributor Paste Purchases, Cooperative Paste Sales, and Grower Nonmember Tomato Sales

			Independent Variables					
Equation	Portfolio Proportion	Constant	Sales Side Cost-Plus Markup (m)	Sales Side Sales-Minus Markdown (n)	Purchase Side Cost-Plus Markup (k)	Purchase Side Sales-Minus Markdown (l)	R^2	Observations
Distributor								
1	W_1	−83.2702	25.9340	187.50000			.999	6
			(1.0826)	(1.4134)				
2	W_2	31.5080	−49.9991	145.9990			.997	6
			(6.6380)	(8.6664)				
3	W_3	52.7622	24.0651	−333.4990			—	6
Cooperative								
4	V_1	26.5474	−8.9486	−55.7513			.998	12
			(.2775)	(1.2786)				
5	V_2	−12.4668	19.0460	−53.6908			.996	12
			(.3893)	(1.7937)				
6	V_3	−13.0806	−10.0974	109.4421			—	12
Grower								
7	S_1	3.5167			−.3087	−7.7811	.987	6
					(.0147)			
8	S_2	−2.3644			1.7706	.2576	.894	6
					(.3616)	(1.2980)		
9	S_3	−.9023			−1.4619	7.5235	—	6

Note: Each regression coefficient indicates the change in a portfolio proportion (base = 100) when the appropriate price parameter rises by .01. Standard errors in parentheses, and R-squares, are shown to give some idea of closeness of fit; they have no statistical content because the data are generated deterministically. Note that equations for W_3, V_3, and S_3 are developed by identities $W_3 = 1 - W_1 - W_2$, $V_3 = 1 - V_1 - V_2$, and $S_3 = .25 - S_1 - S_2$.

Distributor

The distributor's input demand curves (representing own effects) for cost-plus and sales-minus options are negatively sloped in table 2, a result unambiguously predicted for risk-averse firms. Increases in m or n lower profit mean and increase profit variance; the firm loses satisfaction on both counts and reacts by lowering the associated portfolio proportion W_2 or W_3. All cross-effects between price parameters m, n, and unassociated portfolio proportions, including the market price purchase proportion, are positive, as required for substitutes when own effects are negative.

The narrow price parameter domain (1.36 to 1.38 for cost-plus, .255 to .257 for sales-minus) compatible with generally nonzero levels for all portfolio proportions is explained partly by the moderately positive covariances encountered among price bases and partly by the distributor's weak risk aversion. Sensitivity of portfolio proportions to changes in own-price parameters is highest for weak risk averters because the variance-reducing possibilities of portfolio combinations are least noticed by these decision makers.

Given the contract price-basis means used in this study, the expected values of all distributor contract options are equal at $m = 1.40$, $n = .25$. In the limiting case, therefore, in which the decision maker is risk-neutral, he would wish to sign all purchase contracts at market price if $m > 1.4$ and $n > .25$. At $m < 1.4$ or $n < .25$, all contracts would be desired at cost-plus or all at sales-minus. Thus, the normally imposed assumption of risk neutrality represents the most extreme sensitivity of portfolio proportions to price parameter changes, and introduction of even weak risk aversion serves to stabilize portfolios to some degree. One might argue that sensitivity is so great in the distributor's case that risk-neutral behavior is approximated; under that approximation, the distributor may take $m = 1.40$, $n = .25$ as its focus for decision making.

Cooperative

A priori expectations of the cooperative's supply-curve own effects are not as unambiguous as they are for the distributor's demand-curve own effects. For sales portfolios, increases in price parameters (here m or n) raise both profit expectation and variance; the risk-averting decision maker gains satisfaction on the first count and loses it on the second. Because in the expectation of the Taylor expansion on a utility function the variance effect is halved, only a highly risk-averse decision maker would value the variance effect greater than the mean effect. In the present case the cooperative chooses the more usual path and exhibits positively sloped own-price supply functions.

In the face of moderate positive covariances among contract price bases, contract options are substitutes, and cross-price effects are negative as required for substitutes when own effects are positive. Portfolio sensitivity to price parameter changes is lower here than for the distributor. A much wider range of price parameter levels would be involved if attention were extended to portfolio domains over which only two contracts are held at nonzero levels. Owing to covariances between contractual and noncontractual revenues and costs, portfolio sensitivity was also strongly affected by the presence of these noncontractual terms.

The 75,800 tons of tomato paste sold annually by the cooperative represents an expected net margin that is considerably higher than the midpoint net margin on its utility function. Offer curves subsequently generated for paste volumes approximating the utility midpoint were so price-parameter sensitive that even paste sale behavior approached risk neutrality. Even at the midpoint, results may have been considerably less price-parameter sensitive had contract price bases been negatively correlated.

Grower

As with the coop supply curves, all grower-curve own effects are positive. All cross-effects are negative except that increases in sales-minus parameter l appear to have a negligible effect on the quantity of tomatoes supplied on a cost-plus basis. This is consistent with the nearly zero correlation between the sales-minus and cost-plus price bases ($MP_{pst}^{tr} Y_{tom}^{a}$ and VCG_{tom}^{a}, respectively). In the presence of low correlation, the degree of substitutability or complementarity between these options depends upon the aggregate effect of all other covariances in the model.

As with the cooperative model, grower-expected profit at all price parameter levels is higher than the profit midpoint on the grower's

utility-of-profit function. Solutions near the profit midpoint approximated risk neutrality, so that expected utility was maximized by simply selecting the maximum expected profit contract option.

Contract Equilibrium

Specific optimal portfolios for the three firms that are consistent with mutual trade are found by satisfying the market clearing conditions. If it had been possible to develop interior-solution, tomato-contract demand curves for the cooperative, market clearing would have been established by setting $V_1 = W_1$, $V_2 = W_2$, $R_1 = S_1$, and $R_2 = S_2$, and solving the equations simultaneously. Under the circumstances, we develop separate equilibrium solutions for paste and tomato markets. For the paste market, we set $V_1 = W_1$ and $V_2 = W_2$ in table 2, and solve the equation pairs to obtain market-clearing-price parameter levels $m = 1.37311$, $n = .25455$. The corresponding equilibrium paste portfolio shares are $W_2 = V_2 = .018$, $W_3 = V_3 = .914$.

For the tomato market, we appeal to boundary offer curves where $R_3 = 0$, $0 < R_1, R_2 < .25$, and where $S_3 = 0$, $0 < S_1, S_2 < .25$. The associated linear offer-curve estimates are $R_1 = -177.4560 + 132.8530\,k$; $R_2 = .25 - R_1$; $S_1 = 2.5204 - 1.7920\,k$; $S_2 = .25 - S_1$. Setting $R_1 = S_1$, we obtain the market clearing cost-plus markup level $k = 1.3367$. This value is consistent with equilibrium tomato portfolio proportions $R_1 = S_1 = .125$, $R_2 = S_2 = .125$.

As a result, the 75,800 tons of paste sold by cooperative to distributor are divided 6.8% or 5,154 tons on a market price basis, 1.8% or 1,365 tons by cost-plus, and 91.4% or 69,281 tons by sales-minus. The 18,860 tomato acres contracted for purchase with growers are divided 75% or 14,145 acres to members, 12.5% or 2,357.5 acres at market price, 12.5% or 2,357.5 acres at cost-plus, and nothing at sales-minus. This may be interpreted as a competitive bargaining solution since no firm was assumed to have a negotiating advantage. When interior and boundary values were used together in offer curve estimates, the simultaneous paste market and tomato market equilibrium trade solution was $W_1 = V_1 = .123$, $W_2 = V_2 = .087$, $W_3 = V_3 = .790$, $R_1 = S_1 = .038$, $R_2 = S_2 = .091$, $R_3 = S_3 = .121$. This more elegant result was abandoned due to the bias problem discussed earlier. Clearly the bias is more prominent in the tomato market solution, a fact traceable to high sensitivity of cooperative purchase portfolios to price parameter changes.

Summary and Conclusions

The model developed here provides an expected-utility framework for analyzing intra-firm selection of marketing contract portfolios and inter-firm agreement on contract provisions. Under restricted cost-plus and sales-minus parameter ranges, and for a restricted range of the utility-of-profit function, risk-averse firms benefit by employing two or three price options simultaneously, even though most price bases are positively correlated. Offer curves for contract options exhibit own- and cross-effects with signs similar to neoclassical analysis. Contract portfolio sensitivity to price parameter changes is strongly affected by the presence of noncontractual trade terms.

Although the utility functions representing cooperative and grower appear from their concavity to reflect moderate to strong risk aversion, contract offer curves generated near the midpoints of these functions were so price-parameter sensitive as to approximate risk-neutral behavior. Sensitivity would have decreased with less positive or more negative price basis covariances, but there is at least room for skepticism that farmers and processors with concave utility invariably select risk-averse portfolios.

The contracting issues raised here form only a part of the firm's general marketing problem. Subsequent applied investigations might profitably consider contract quantity clauses; risks of inadequate inventory; contract allocations across alternative buyers, sellers, or types of goods; and the impact of generalized adoption of long-term marketing contracts.

[*Received December 1977; revision accepted February 1979.*]

References

Anderson, J. R., J. L. Dillon, and J. B. Hardaker. *Agricultural Decision Analysis*. Ames: Iowa State University Press, 1977.

Barry, P. J., and D. R. Willmann. "A Risk-Programming Analysis of Forward Contracting with Credit Constraints." *Amer. J. Agr. Econ.* 58(1976):62–70.

Buccola, S. T., and B. C. French. "An E-V Analysis of Pricing Alternatives for Long-Term Marketing Contracts." *S. J. Agr. Econ.* 9(1977):17–23.

Eidman, V. R., G. W. Dean, and H. O. Carter. "An Application of Statistical Decision Theory to Commercial Turkey Production." *J. Farm Econ.* 49(1967):852–68.

Hardie, I. W. "Shadow Prices as Member Returns for a Marketing Cooperative." *Amer. J. Agr. Econ.* 51(1969):818–33.

Harris, M., and D. T. Massey. *Vertical Coordination Via Contract Farming.* USDA ERS, Misc. Publ. No. 1073, 1968.

Helmberger, P., and S. Hoos. "Cooperative Enterprise and Organization Theory." *J. Farm. Econ.* 44 (1962):275–90.

Jesse, E. V., and A. C. Johnson, Jr. "An Analysis of Vegetable Contracts." *Amer. J. Agr. Econ.* 52 (1970):545–54.

Kmenta, J. *Elements of Econometrics.* New York: Macmillan Co., 1971.

Ladd, G. W. "A Model of a Bargaining Cooperative." *Amer. J. Agr. Econ.* 56(1974):509–19.

Von Neumann, J., and O. Morgenstern. *Theory of Games and Economic Behavior.* Princeton, N.J.: Princeton University Press, 1947.

Food Price and Supply Stabilization: National Buffer Stocks and Trade Policies

David Bigman and Shlomo Reutlinger

Trade policies are likely to have a greater impact on the stability of a country's food grain supply than any reasonable size buffer stock. At the margin, countries need to trade off the cost of additional stocks against the cost of unstable foreign exchange balances associated with free trade. A stochastic simulation model is specified to assess the impact of trade and buffer stock policies on the stability of consumption and prices and the expected values and standard deviations of costs and gains to consumers, producers, and the government, and the balance of payments.

Key words: buffer stocks, food grains, stabilization, trade policies.

The stability of food grain supply and price is of continuous concern to many governments. In the past decade, fluctuations of grain prices and the threat of widespread famine in times of major crop failures have become a major preoccupation of the international community. In most discussions, both at the theoretical and at the policy-making level, attention is on national and international stock policies as the main instrument of stabilization (Turnovsky). In practice, however, most governments are engaged in a wide variety of policies that have direct or indirect effects on food grain supply and price. They include subsidies to low income families, support prices to farmers, and various trade policies relating to agricultural products (Sarris, Abbot, Taylor).

The effects of international trade, in general, and of trade policies, in particular, on domestic food grain supply and prices have not always been appreciated adequately; and as a result, free trade in these products is unpopular in many quarters. It often has been accused of depressing agricultural production in importing countries, increasing their dependence on the exporters of these products, and thereby exposing them to a higher risk of shortages in supply. At times of poor domestic harvests and/or high prices for imported grain, it is not uncommon for governments to pronounce themselves in favor of large buffer stocks while protectionist sentiments grow stronger. Free trade is presumed to "import" instability because of the growing dependence on surpluses that may be temporary. Isolation from the world market combined with national stock policy would thus not only encourage domestic food production but also reduce instability in the domestic market.

This paper has three principal objectives: first, to analyze the effects of international trade on the domestic market of food grains, particularly on the stability of domestic supply and price; second, to examine the contribution of internal policies—notably subsidy and stock policies—and of external policies—notably free trade versus restricted trade—on the stability of grain prices and supplies; third, to provide estimates for the direct financial costs, the overall economic costs, and the distributional consequences of the various policies and programs.

We commence the analysis by discussing the limitations of some of the strong assumptions which are necessary in the more stylized models generally used in the theoretical litera-

---

David Bigman is an economist with the International Monetary Fund, and Shlomo Reutlinger is a senior economist at the World Bank.

This paper is part of an extensive study undertaken by the World Bank (RPO 671-24) on various aspects of food market stabilization policies. Some results have been already reported by Reutlinger; Reutlinger, Eaton, Bigman; and Bigman and Reutlinger.

The authors wish to thank the numerous persons who provided comments and advice. In particular, they express their gratitude to David Eaton, Bruce Arntzen, David Blum, and Keith Knapp, who participated at various stages of the study. The views expressed in this paper are those of the authors and are not to be attributed to the International Monetary Fund or the World Bank.

ture. To overcome these limitations, we develop a simulation model which provides a framework for analyzing (*a*) the extent to which annual instability in a country's food grain production and the world market price of food grains translate into instability in the country's food grain consumption and price under alternative trade policies and market structures, and (*b*) the extent to which a buffer stock of varying sizes contributes stabilization, at what social and financial costs or gains, to producers, consumers, and the government. While our method of analysis lends itself to consideration of a wide range of domestic and external trade policies, we have opted to emphasize the effect of protectionist trade policies. Our analysis leads to the conclusion that for most countries, especially the developing countries, free trade and avoidance of protectionist policies would be a far more powerful instrument for stabilizing domestic grain prices and ensuring the continuity of supplies than any reasonably sized buffer stock.

The Analytical Framework

The merits of stabilization policies from a theoretical point of view have been discussed quite extensively by economists. Most have taken the approach initially advanced by Waugh, Oi, and Massel (1969, 1970) and have examined the welfare implications of price stabilization as measured by changes in consumer and producer surplus. The early literature on the subject dealt with a single market in a close economy. In recent years, however, increasing attention has been paid to price stabilization in international trade. Hueth and Schmitz have extended the basic framework of Waugh, Oi, and Massel to examine the welfare gains from stabilizing the price of internationally traded goods. Just et al. (1977) examined the distribution of welfare gains from international price stabilization under distortions.

It has been recognized, however, that the scope of this analytical framework is quite limited because a number of common assumptions underlying the Waugh-Oi-Massel analysis and most of the subsequent literature are highly restrictive (see Just et al. 1976, 1977; Turnovsky). First, a key assumption in most of these works is that of linear demand and supply schedules. Recently it has been demonstrated that certain important propositions of this analysis do not generalize to the nonlinear case. Second, a typical assumption in this model is that of complete price stabilization, achieved by means of a sufficiently large buffer stock; that is, a buffer stock of the commodity is set up which is large enough to ensure a fixed price for any random disturbance. It is quite apparent that the cost of a "sufficiently large" stock required for complete stabilization invariably would exceed the gains. In practice, the authorities are more likely to set an upper limit on storage capacity and to engage in only partial stabilization. Practical interest, therefore, focuses on gains and costs from partial stabilization and on the degree of stability achievable with a given storage capacity. Third, the costs of operating the buffer stocks and maintaining the storage facilities generally are ignored. Our analysis shows that taking these costs into account drastically changes and often reverses the conclusions about the benefits of stabilization. Fourth, the Waugh-Oi-Massel analysis assumes supply and demand to be determined by the actual market price. On the supply side, especially with regard to agricultural commodities, this assumption is unrealistic because most, if not all, production decisions are made before the actual price is known (on the basis of expected price). Fifth, in the context of the two-country model, the analysis of Hueth and Schmitz assumes away trade barriers such as transportation costs and tariffs. For a country which is normally self-sufficient, these barriers may prohibit trade even when there is a price differential between the domestic and the international market. Trade will be permitted only at times of a severe shortfall or large excesses in domestic production. From an analytical point of view, taking these barriers into account may make the analysis almost unmanageable.

These restrictive assumptions, which are rather technical in nature, raise serious doubts about the validity of the propositions emerging from the Waugh-Oi-Massel type analysis. We find, however, more fundamental difficulties with this approach. Most important, this analysis evaluates the desirability of price stabilization on the basis of welfare gains only. Stabilization is presumed to be desirable only to the extent that it increases the combined consumer and producer surplus. We argue that while economic efficiency is an important consideration, it is only one among several objectives of stabilization policy. In most countries the primary objective of buffer stocks and other stabilization policies is to

ensure a regular flow of supplies to consumers and to meet the needs of vulnerable sections of the population. A recent study undertaken by the United Nations Food and Agriculture Organization (FAO) shows that most countries rate the insurance of a continuous flow of supply as the main objective of their cereal stock policies. The promise of welfare gains "over the long run" from price instability provides only little comfort to consumers who may find themselves unable to buy food at times of very high prices. In our view, the expected economic and financial losses to consumers, and possibly also to the economy at large, due to price stabilization should be regarded as an insurance premium paid by the market participants in order to avoid scarcity and famine. In addition, stabilization of food prices may have significant macroeconomic effects which a complete cost-benefit analysis must take into account.

Another weakness of this analytical work is its vagueness regarding the mechanism and the specific policy instruments engaged in stabilization. Typically, in this literature the desirability of price stabilization is assessed by comparing two extreme cases: one in which prices are permitted to fluctuate freely, and the other in which the price is fixed. In practice, governments implement a variety of policies affecting the level of stability of commodity prices, such as price supports for farmers, subsidized rations to low income consumers, and various controls on imports and exports. In assessing the desirability of buffer stocks, for example, the relevant question is what are the incremental effects of stocks on prices and on welfare, given the price policies which already are practiced. In a more general context, the inquiry should be extended to analyze the effectiveness of different combinations of policies in achieving prespecified stabilization goals.

Finally, little attention has been paid in the literature to the stabilizing (but potentially also destabilizing) effects of international trade per se. An open economy can offset potential price instability caused by fluctuations in domestic supply through exports and imports. On the other hand, trade can transmit fluctuations in supply in other countries to the domestic market. Consequently, the possible gains from stabilization measures in a given country will differ substantially in the presence or absence of trade.

The stochastic simulation model presented was developed to demonstrate that economists can do better in providing analytical underpinnings to policy than to espouse general propositions whose validity depends on a large number of unrealistically restrictive assumptions about the nature of the problem and the objectives of stabilization policy. We have no reservations in recommending the stochastic simulation-modeling approach for the purpose of analyzing the consequences of policy in a specified environment. However, we are aware, and the reader should be aware, that this approach cannot and does not yield readily definable generalizations because the results will depend on the specific parameters applied in the analysis. By means of sensitivity analysis we are able, however, to determine the range of applicability of our conclusions.

The Model

The model is of an open economy principally concerned with stabilization policies for food grains. It examines the effects of random fluctuations in the country's production and in the international price of grain on the various parameters of the domestic market, such as prices, quantities available for consumption for individual consumer groups, welfare gains and losses, the fiscal budget, and the balance of payments—given a set of policies implemented by the government. The country is assumed to be "self-sufficient" in the sense that in a "normal" year, when both the country's production and the world price are at their median level, there would be no differential between the price in the world and in the country to provide an incentive for trade. Yet random fluctuations in the supply of either the country or the world may create at times price differentials to an extent that despite transportation costs and tariffs, imports or exports could occur. Thus, even countries which embark on the objective of self-sufficiency in food supply can realize substantial gains from trade as a consequence of (uncorrelated) random fluctuations between food grain production in the country and in the rest of the world.

For any given level of grain production in the world and in the country, the model estimates (*a*) world price; (*b*) price and quantity of grain consumed, stored, and traded by the country; and (*c*) gains and losses to consumers, producers, government, and society. The structure of the model is described briefly below.

World Price

Examination of the effect of trade policies on the stability of a country's grain market requires an estimate of the distribution of the world price. Because there is little direct historical evidence for estimating future variability of the world price, a simple (much too simple a model for other purposes) world price model is postulated which transforms any production level into a world price on the basis of a prespecified world demand function. World production is a random variable with a specified probability distribution.

Country's Production

Production of grain in the country is a random variable with a specified probability distribution. In the present version of the model, planned production remains constant, i.e., the model is stationary. The implicit assumption permitting extrapolation of the results from the model over time is that the growth rates of food production and consumption are equal, so that the country remains self-sufficient. Allowances are made for the possibility of year-to-year serial correlation in production and for correlation between the country's production and world production (and, therefore, the world price).

Country's Demand

The country's demand for grain is assumed to consist of the combined demand of two consumer groups defined by income levels, a low income group and all other consumers. The government is assumed to have an explicit food policy by which the low income group's consumption is assured not to fall below a desired level by means of an adequate subsidy program. The demand function for the economy at large is piecewise linear with a kink at the mean, reflecting the inelastic demand induced by the government's intervention on behalf of the low income group when supplies are scarce.

International Trade

Trade activities between the country and the world are carried out by the free market within limits of a specific trade policy implemented by the government. Thus, grain is imported when the domestic price exceeds the import price and exported when the export price exceeds the domestic price. Import and export prices are determined by the world price, transportation costs, and tariffs. The instruments for enforcing government goals with respect to trade are tariffs. Those goals need not be restricted to the balance of payments and we also have considered policies deliberately designed to prevent wide fluctuations in supply or price beyond certain critical levels caused by trade. Thus, exports are not permitted when the quantity available for domestic consumption is below a prespecified lower level, and import is restricted never to let the domestic price fall below a specified lower limit.

Storage Policies

Storage policies consist of rules which determine the desired amount of grain to be stored or released in any year and a storage capacity constraining the actual level of storage activity. In the present paper, storage rules are defined by a quantity band. Within the boundaries of the band, supply is allowed to fluctuate freely with no storage activity. When domestic production (Q) exceeds the upper limit of the band (Q_H), the amount of grain stored is the excess of production above Q_H—up to the capacity limit of the facility. When production is less than the lower limit of the band (Q_L), the amount of grain taken out of storage is the amount by which production falls short of Q_L—up to the quantity limit of grain available in storage.

It should be noted that trade and storage activities can substitute for each other on occasion to achieve stabilization objectives. When production is short, the world price is low and stored up grain is available, grain can be imported or withdrawn from storage. Likewise, when production is plentiful, export prices are high and there is vacant storage capacity, grain can be exported or stored. We assume that the authorities emphasize the food security aspect of the storage operations; and thus grain is imported prior to releasing from storage in times of scarcity, and excess supply is put first into storage and only the remaining quantity is released for exports in times of good domestic harvest.

One point is worth emphasizing with respect to these storage rules: the domestic price in any given year depends on the quantity produced domestically, the world price, and the

quantity of grain in storage—or the vacant storage capacity—at that year. The latter, in turn, depends on the quantities of grain produced domestically, on world prices in previous years, and on the initial stock and the storage capacity. Consequently, some degree of serial correlation is introduced into the time series of domestic prices due to the storage operations, even when production events are not correlated.

Gains and Losses from Stock Operation

The gains and losses from buffer stocks to society and their distribution among consumers, producers, and the government depend largely on the difference between the price of grain with and without stock operations. When grain is withdrawn from the market into storage, the price is raised; consumers lose and producers gain. Vice versa, when grain is withdrawn from storage to augment current supply, the price is reduced; consumers gain and producers lose.

These gains and losses, as well as the costs and revenues to the government when grain is put into or withdrawn from storage, are illustrated in figures 1(a) and 1(b) and are summarized in table 1 in terms of the designated areas on the graph. The quantity available for current consumption without storage is Q and with storage Q'. P and P' are the corresponding prices without and with storage.

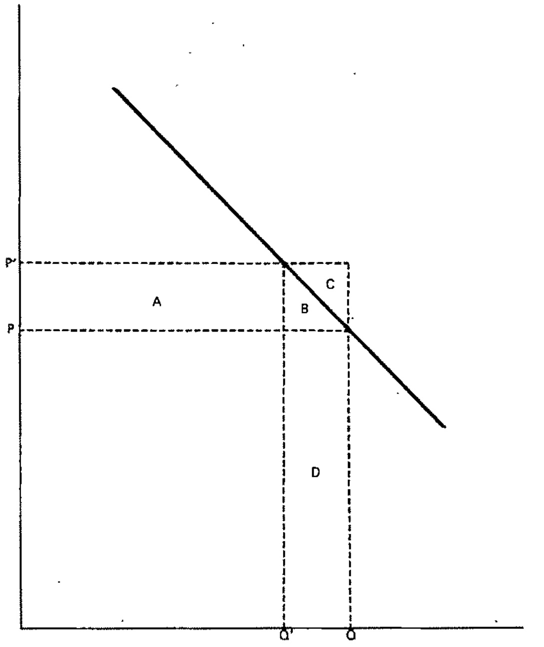


Figure 1(a). Gains and losses from storage operation: grain into storage

Total market demand is assumed to be the sum of the separate demand of "low" and "high" income consumers. Consumption of

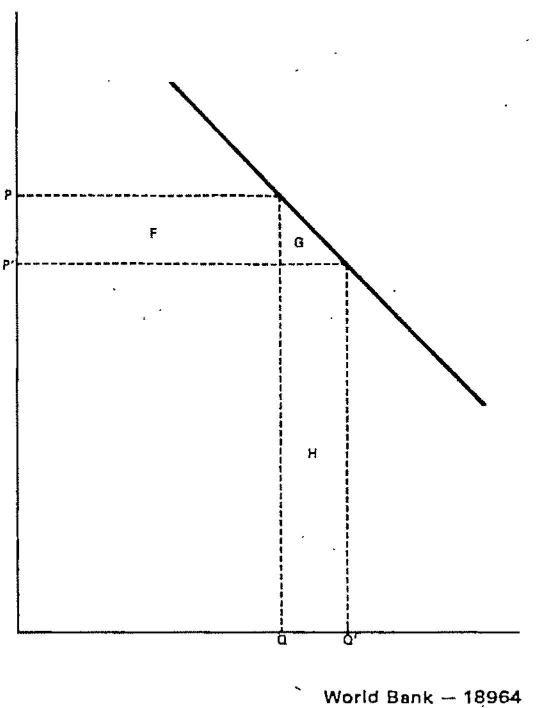


Figure 1(b). Gains and losses from storage operation: grain out of storage

Data and Parameters

The specific parameters selected for the simulation experiments are not representative of any particular country; they are, however, deliberately chosen to approximate orders of magnitude of a country like India. This section describes briefly the data and parameters underlying illustrative results presented in the next section.

The results reported in this paper were obtained by simulating 300 runs of thirty-year sequences of random production "events." The total sample size consists, therefore, of 9,000 observations drawn at random from the specified probability distributions.

The country is assumed to produce an average of 110 million tons of food grains. Specifically, production is assumed to be distributed normally, with a mean of 110 million tons and a standard deviation of 7 million tons.

Table 1. Types of Gains and Losses When Grain Is Stored and When Grain Is Withdrawn from Storage by Reference to Areas Shown in Figure 1a–1b

Types of Gains and Losses	Designated Area of Gain or Loss
Grain into storage [Fig. 1(a)]	
Consumers	− A − B
Producers	A + B + C
Government (financial)	− B − C − D
Overall (economic)	− B − D
Grain withdrawn from storage [Fig. 1(b)]	
Consumers	F + G
Producers	− F
Government (financial)	H
Overall (economic)	G + H

the "low" income population is maintained through government intervention at a minimum level. This level is assumed to correspond with the "low" income population's consumption at the median price of $125 per ton. The consumption maintenance policy is implemented through a price subsidy scheme for the low income population. The specific parameters of the demand schedules adopted for the numerical analysis are listed in table 2. Equal food grain consumption by the low and the high income group at the median price of $125 subsumes that the low income group consists of more than half of the total population and per capita consumption is less in the low income group.

World wheat production is assumed to be distributed normally, with a mean of 350 million tons and a standard deviation of 14 million tons. This distribution is transformed to a distribution of the world price on the basis of a kinked demand function. At the mean level of world production, the price is $125 per ton, and the price elasticities of the two segments of the demand function at that point are as follows:

$$\eta = 0.1 \text{ for } P > \$125$$
$$\eta = 0.3 \text{ for } P > \$125.$$

Notice that while production is assumed to be distributed normally, the transformed distribution of price is skewed, with its mean being larger than the median.

Shipping costs are assumed to be $25 per ton. Trade policies are implemented by the level of tariff. In any event, imports are not permitted to reduce the domestic price below .95 of the median price (i.e., increase total supply above 112 million tons). Exports are not permitted to reduce the quantity available for domestic consumption below 108 million tons. In addition, the following general three trade policies are examined in the base case: Free Trade, no tax is imposed on exports or imports; Restricted Trade, the government imposes a tax of $25 per ton on all imports and exports; No Trade, the government imposes a tax high enough to rule out all trade.

Grain production in excess of 112 million tons is put into storage to the extent that there is vacant storage capacity. Grain is taken out of storage when domestic production is less than 108 million tons to the extent of the deficit or to the extent of available stocks in storage, provided the world price is so high as to prevent any imports. A handling charge of $2 per ton is assumed at the time grain is loaded into storage. The rate of interest is 8%; construction costs are assumed to be $100 per ton of capacity and storage facilities are assumed to be amortized within a period of thirty years.

Simulation Results

Tables 3 and 4 summarize the stabilization effects of buffer stocks and of the three trade policies. Our attention is given to the stability of food grain supply, and specifically, on the lower tail of its probability distribution;

Table 2. Country Demand Parameters

	"Low" Income Population	"High" Income Population	Total Population
Quantity consumed (million tons) at $P = \$125$	55	55	110
Price Elasticity of demand			
for $P < \$125$	0.4	0.2	0.3
for $P > \$125$	0.0	0.2	0.1

Table 3. Stability of Food Grain Consumption under Alternative Trade Policies, with and without a Buffer Stock

	No Trade		Restricted Trade		Free Trade	
Storage Capacity: (mill. tons):	0	6	0	6	0	6
	Probability (%)					
	No Correlation between Country and World Production					
Consumption (million tons)						
< 100	7.2	4.2	0.8	0.4	0.3	0.1
100 – 105	16.3	9.9	9.8	5.2	5.9	2.9
105 – 115	52.9	72.0	72.4	83.6	81.1	88.0
115 – 120	16.0	10.2	12.4	8.3	11.0	8.0
> 120	7.6	3.7	4.6	2.5	1.7	1.0
	Correlation (R^2 = 0.3) between Country and World Production					
Consumption (million tons)						
< 100	7.2	4.2	1.8	1.0	0.7	0.3
100 – 105	16.3	9.9	12.4	7.3	8.5	4.8
105 – 115	52.9	72.0	65.8	78.8	74.2	83.2
115 – 120	16.0	10.2	14.1	9.7	13.5	9.7
> 120	7.6	3.7	5.9	3.2	3.1	1.9

Table 4. Stabilization Effects of Buffer Stocks and Alternative Trade Policies

	No Trade		Restricted Trade		Free Trade	
Storage Capacity (mill. tons)	0	6	0	6	0	6
	No Correlation between Country and World Production					
Consumption (mill. ton)						
Average	110	110	110	110	110	110
(standard deviation)	(6.9)	(5.3)	(5.0)	(4.0)	(3.9)	(3.3)
Price ($/ton)						
Average	145	140	139	136	136	134
(standard deviation)	(54)	(43)	(35)	(28)	(27)	(22)
Balance of trade ($ mill.)						
Average	—	—	3	−2	−4	−16
(standard deviation)	—	—	(600)	(515)	(767)	(696)
Subsidy payments ($ bill.)						
Average	1.70	1.20	1.17	0.93	0.90	0.75
(standard deviation)	(2.5)	(2.05)	(1.47)	(1.18)	(1.15)	(0.90)
Farmers' revenue ($ bill.)						
Average	15.65	15.20	15.07	14.82	14.80	14.64
(standard deviation)	(4.75)	(3.60)	(3.04)	(2.30)	(2.43)	(1.94)
	Correlation (R^2 = 0.3) between Country and World Production					
Consumption (mill. ton)						
Average	110	110	110	110	110	110
(standard deviation)	(6.9)	(5.3)	(5.6)	(4.5)	(4.6)	(3.8)
Price ($/ton)						
Average	145	140	140	137	137	135
(standard deviation)	(54)	(43)	(40)	(32)	(32)	(26)
Balance of trade ($ mill.)						
Average	—	—	−40	−31	−54	−43
(standard deviation)	—	—	(452)	(392)	(626)	(567)
Subsidy payments ($ bill.)						
Average	1.70	1.25	1.30	1.00	1.00	0.85
(standard deviation)	(2.50)	(2.05)	(1.70)	(1.40)	(1.35)	(1.10)
Farmers' revenue ($ bill.)						
Average	15.65	15.20	15.10	14.85	14.85	14.65
(standard deviation)	(4.75)	(3.60)	(3.40)	(2.60)	(2.80)	(2.20)

namely, the events of extreme shortfalls in the quantity available for consumption.

A noteworthy characteristic of our results is the strong stabilizing effect of international trade which far exceeds the effect of a sizeable buffer stock. The standard deviation of the quantity available for consumption is 6.9 million tons (6.3% of mean consumption) in the closed economy compared with 3.9 million tons (3.5% of mean consumption) under free trade. The probability of a shortage in excess of 5 million tons is 23.5% in the closed economy compared with 6.2% under free trade. In contrast, a buffer stock of 6 million tons in the closed economy reduces the standard deviation of the quantity available for consumption from 6.9 million to 6.3 million tons and the probability of a shortage in excess of 5 million tons from 23.5% to 14.1%. Equally noteworthy is the fact that as the country becomes more open to trade, the additional stabilizing effect of buffer stocks is progressively reduced. Thus, for instance, a buffer stock of 6 million tons reduces the standard deviation of the quantity available for consumption by 25%—from 6.9 million tons to 5.3 million tons—in the closed economy but by only 15%—from 3.9 million to 3.3 million tons—in the open economy.

The extent to which trade and stocks stabilize grain consumption and prices will depend, of course, on the relative variability of the world price and the country's price in the absence of trade. The country's price in the absence of trade will depend on its production variability and the shape of its demand function. To investigate the sensitivity of our conclusions, we simulated the effects of trade and stocks under two alternative assumptions about the variability of production in the country: "more stable" production (a coefficient of variation half that assumed in the base case) and "less stable" production (a coefficient of variation twice that assumed in the base case). The standard deviation of price ($/ton) with free trade or, alternatively, with a 6 million ton buffer stock under different scenarios is as follows:

	No Trade No Stock	Free Trade	6 Million Ton Stock
Base case	54	27	43
"More stable" production	27	19	21
"Less stable" production	108	33	94

Our results also indicate that a moderate degree of correlation between the country's grain production and that in the world does not change our basic conclusions. With a correlation coefficient of $R^2 = 0.3$, for instance, the standard deviation of the quantity available for consumption would still be reduced by 35%—from 6.9 to 4.6 million tons—with free trade (compared, however, with 45% when there is no such correlation).

Figure 2 illustrates the extent of supply stabilization attained by the three trade policies and by increasing sizes of buffer stocks (storage capacities). Here attention is given the availability of food grain for consumption measured by the probability of a serious shortfall in grain consumption. The graph illustrates that even as large a buffer stock as 12 million tons (11% of annual average consumption) would not provide the same degree of protection against extreme shortfalls as would free trade. The slope of the curves manifests the marginal stabilizing effect of each additional unit of storage capacity. Clearly, the marginal effect becomes smaller as trade restrictions are relaxed, and in all cases it declines sharply with increases in storage capacity. For instance, an increase in storage capacity from 6 million to 9 million tons would reduce the probability of a shortage in excess of 5 million tons from 14% to 11% if no trade is permitted, but from 3% to only 2.5%, if trade is free. Without trade, increasing the storage capacity from 0 to 6 million tons would reduce the probability of a shortage in excess of 5 million tons from 24% to 14% but a further increase from 6 million to 12 million tons would reduce this probability only from 14% to 11%.

One conclusion of these results is that the stabilization benefit from a buffer stock is generally much higher in a closed economy than in an economy open to trade. The diminished effect of stocks in an open economy also is reflected in its economic and financial benefits and costs. In general, net gains from storage operation are larger, the larger is the number of transactions (acquisitions for and sales from storage) and the larger is the difference between the price at which grain is purchased and sold.

In the free market economy, trade activities can replace storage activities and the variability of grain prices is generally reduced. As a result, buffer stocks would be operated much less frequently and the differential between

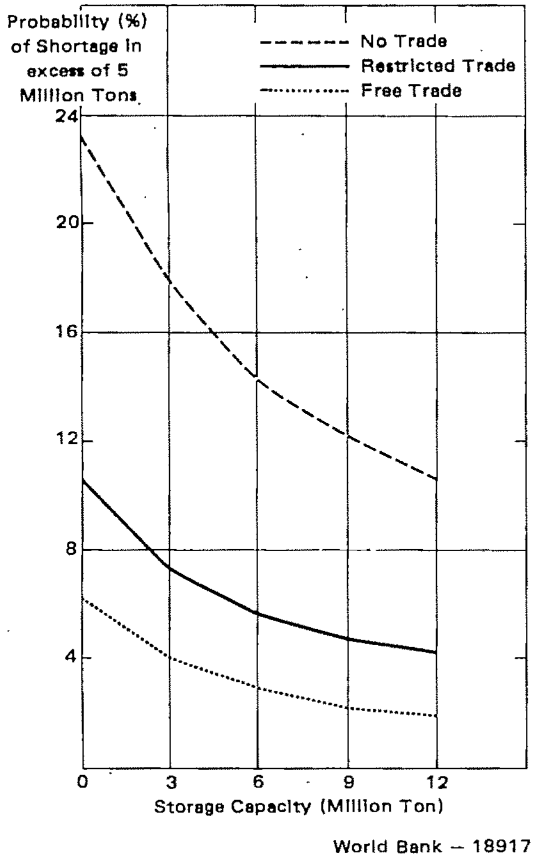


Figure 2. Relative frequency of serious supply shortfall with alternative storage capacities and trade policies

the purchase price and the sale price would be considerably lower in the open economy. The net result would be smaller gains, and even losses, from the operation of the storage facility to the extent that the amortization costs would far outweigh any possible gains.

Table 5 summarizes the gains and losses to society as a whole and their distribution among consumers, producers, and the government from a 6 million ton capacity storage operation. In a closed economy, net annual economic losses from a 6 million ton buffer stock would be relatively small ($12 million annually). However, in an open economy, the same size of buffer stock would not only contribute much less to stabilization but would also be much more costly ($70 million annually).

The distribution of losses and gains is, however, by far more important than the overall amounts. With the demand function specified in our model, price stabilization normally would yield gains to consumers and losses to producers. Our results show, however, that consumers would suffer losses rather than gain. The reason is that under the postulated subsidy program, low income consumers do not gain from the reduction in price when grain is removed from storage. They would pay the same subsidized price regardless of the actual market price when supplies are scarce. When

Table 5. Annual Economic and Financial Gains (Losses) from a 6 Million Ton Capacity Storage Operation

	No Trade	Restricted Trade	Free Trade
No Correlation between Country and World Production			
($ million)			
Total economic gains	−12	−59	−73
Consumer gains	−30	−35	−8
Producer gains	−380	−180	−125
Storage operation account[a]	−37	−62	−79
Change in tax revenue[b]	—	−12	−4
Saving on subsidy	435	230	143
Total government account	398	156	60
Correlation (R^2 = 0.3) between Country and World Production			
Total economic gains	−12	−46	−60
Consumer gains	−30	−65	−33
Producer gains	−380	−183	−131
Storage operation account[a]	−37	−53	−69
Changes in tax revenue[b]	—	−9	−2
Savings in subsidy	435	264	175
Total government account	398	202	104

[a] Including $53 million amortization costs.
[b] "Quantity restrictions" on imports and exports are implemented by an appropriate tariff. Thus, the government will have some tax revenues even under a "free trade" policy.

the subsidy program is practiced, gains from stabilization accrue primarily to the government in the form of saving on subsidy payments.

The more restricted is international trade and the larger is the buffer stock, the larger are these fiscal benefits from stocks. This should not be interpreted, however, to mean that governments should favor protectionist policies and large buffer stocks. To the contrary, the "gains" by the government from stocks only partially compensate for the additional fiscal burden the government incurs in the first place, as a consequence of greater instability in grain prices introduced by the trade restrictions. Put differently, total subsidy payments in the open economy are considerably lower than in the closed economy with buffer stocks.

Figure 3 illustrates the rapidly declining cost effectiveness of increasing levels of buffer stocks under all trade scenarios. While the probability of a shortage in consumption in the excess of 5 million tons declines with increasing stock levels, this increased protection is bought at rapidly accelerating cost to the economy. Only in the closed economy and for a very small stock would there be some gains at the same time that the probability of a shortage would be reduced. Under restricted trade, an annual outlay of $45 million for buffer stocks would reduce the probability of a severe shortfall for approximately 8% to 5%. However, an additional outlay for buffer stocks of the same magnitude would reduce the probability of such a shortfall only an additional 1.1%.

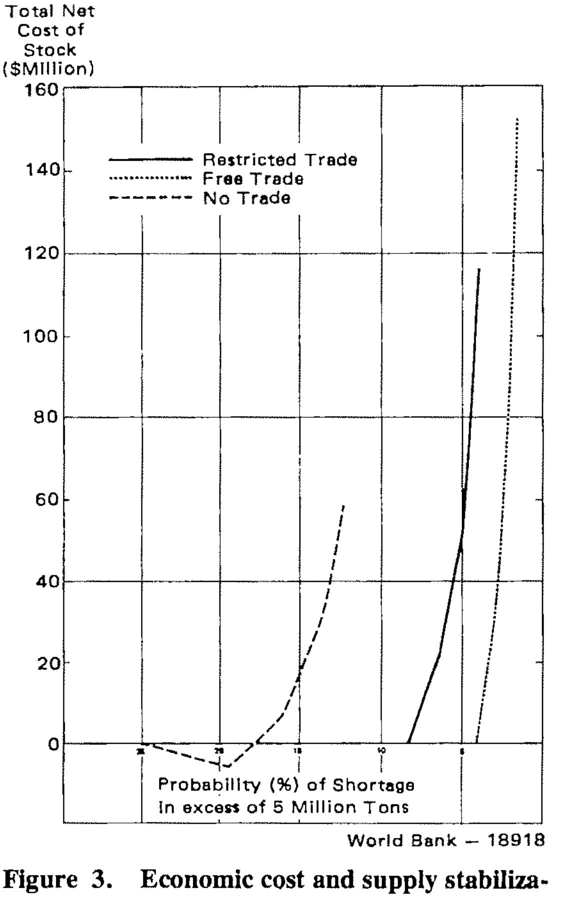


Figure 3. Economic cost and supply stabilization with alternate trade policies

Conclusions

The single most important observation based on our analysis is that for most countries international trade would be a good way of achieving greater stability in the domestic market. Although countries can choose between liberalizing their trade or maintaining buffer stocks as alternative ways of promoting stability, our analysis shows that buffer stocks sufficiently large to stabilize supplies can be very costly. Obviously, the trade option has its own costs as well, in the form of larger fluctuations in foreign exchange balances and the need to draw on large reserves in times of shortfall in domestic production or high world price. In this context and in recognition of the potentially strong stabilizing effects of trade, the international community also should reevaluate the directions of its efforts aimed at ensuring a stable food supply in developing countries.

[Received May 1978; revision accepted April 1979.]

References

Bigman, D., and S. Reutlinger. "National and International Policies Toward Food Security and Price Stabilization." *Amer. Econ. Rev.* 69(May 1979): 159–63.

Food and Agriculture Organization of the United Nations. *Current Status of National Cereal Stock Policies and Targets.* Rome: UN FAO CFS 77/7, 1977.

Hueth, D., and A. Schmitz. "International Trade in Intermediate and Final Goods: Some Welfare Implications of Destabilized Prices." *Quart. J. Econ.* 86 (1972):351–65.

Just, R. E., E. Lutz, A. Schmitz, and S. Turnovsky. "The Distribution of Welfare Gains from Price Stabiliza-

tion: An International Perspective." Dep. Agr. and Resour. Econ. Work. Pap. No. 8, University of California, Berkeley, 1976.

———. "The Distribution of Welfare Gains from International Price Stabilization Under Distortions." *Amer. J. Agr. Econ.* 59(1977):652–61.

Massel, B. F. "Price Stabilization and Welfare." *Quart. J. Econ.* 83(1969):284–98.

———. "Some Welfare Implications of International Price Stabilization." *J. Polit. Econ.* 78(1970):404–17.

Oi, W. Y. "The Desirability of Price Instability Under Perfect Competition." *Econometrica* 29(1961):58–64.

Reutlinger, S. "A Simulation Model for Evaluating Worldwide Buffer Stocks of Wheat." *Amer. J. Agr. Econ.* 58(1976):1–12.

Reutlinger, S., D. J. Eaton, and D. Bigman. "Should Developing Nations Carry Grain Reserves?" *Analysis of Grain Reserves*. eds. D. J. Eaton and W. S. Steel. USDA ERS 634, pp. 12–38, 1976.

Sarris, A. H., P. C. Abbot, and L. Taylor. "Grain Reserves, Emergency Relief and Food Aid." Mimeographed. Washington, D.C.: Overseas Development Council, March 1977.

Turnovsky, S. J. "The Distribution of Welfare Gains from Price Stabilization: A Survey of Some Theoretical Issues." Paper presented at the Ford Foundation Conference on Stabilizing World Commodity Markets, Airlie, Va., March 1977.

Waugh, F. V. "Does the Consumer Benefit from Price Instability?" *Quart. J. Econ.* 58 (1944):603–14.

The Net Social Benefits from a Research-Induced Cost-Reduction of an Energy Backstop Technology

Frank A. Ward

Substantial effort has been devoted to the development of measures of benefit attributable to agricultural research that lowers commodity costs. With increasing scarcity of energy inputs, many research resources are being devoted to overcome this scarcity by reducing the costs of "backstop" technologies, i.e., nonexhaustible sources of energy output. This paper draws from (*a*) the theory of exhaustible resources and (*b*) the literature of traditional surplus measures of benefit and cost, to develop a conceptual framework for quantifying the net social benefit for successful backstop cost-reducing energy research.

Key words: backstop technology, exhaustible resources, research benefits, social cost-benefit.

In recent years, several researchers have developed measures of the benefits from agricultural research. Griliches, Arndt and Ruttan, and Evenson and Kislev all have attempted to estimate the social rate of return on such research. More recently, Lindner and Jarrett developed a generalized measure of research benefits as dependent on the manner in which research affects commodity supply curves. Thus, there would seem to be an emerging consensus for evaluating the social benefits of agricultural research.

This paper attempts to develop a conceptual framework for measuring the net social benefits for energy-related research. The need for a distinct measure of energy research benefits rests on the fact that for much of the world's present-day energy output, exhaustible mineral resources make up a substantial portion of the required factor inputs, and a conceptually acceptable measure of energy research benefits would need to take into account the inherently dynamic nature of exhaustible energy minerals extraction. The development of an acceptable measure requires that this paper bridge two distinct bodies of literature.

On one hand, the concept of net social benefits is heavily dependent on the cost-benefit literature, such as Mishan; Currie, Murphy, and Schmitz; and Lindner and Jarrett. Second, however, an analysis of net benefits as applied to exhaustible energy resources logically should draw from the exhaustible resources literature, such as that of Goldsmith, Hotelling, Herfindahl, Nordhaus, Solow, and Weinstein and Zeckhauser. The present article draws from both sources of literature.

The basic approach of this paper is as follows: Assume that a given form of energy can be supplied by two sources, (*a*) an exhaustible mineral of which there is an absolutely fixed supply, but for which the extraction costs are constant and relatively low, and (*b*) a "backstop technology" (see Nordhaus), a technology of high capital costs, which although not presently economical, nonetheless will not require the use of exhaustible energy resources when the transition is made to this technology. We consider the question: Suppose research effort is directed at reducing the cost of this backstop technology (the B-cost), then what are the net social benefits attributable to that cost reduction?

Frank A. Ward is assistant professor of agricultural economics in the Department of Agricultural Economics and Agricultural Business, New Mexico State University, Las Cruces.

The author wishes to express his appreciation for helpful comments by John R. McKean, Thomas Clevenger, and Martin Blake, and two *Journal* reviewers. The author alone is responsible for remaining errors or omissions.

Journal Article No. 699, Agricultural Experiment Station, New Mexico State University, Las Cruces.

Assumptions, Definitions, and a Brief Review of the Basic Economics of Exhaustible Resources

Following Hotelling, Herfindahl, and Solow, it is assumed that the exhaustible resource (the E-source) market is made up of price takers who face constant costs and a parametrically invariant demand schedule. That is, the marginal cost schedule of resource extraction is horizontal and does not shift up with the cumulative quantity mined. All deposits of a specific homogeneous exhaustible resource are fully known and individually appropriated. Each producer is a price taker, but economic profits do not draw in additional producers, because the mineral supply is fixed. Furthermore, each mine owner discounts future profits at the same discount rate, assumed equal to the marginal social rate of time preference. Under these assumptions, at any point in time, equilibrium market price exceeds extraction costs where the residual (a scarcity rent referred to as a "royalty" in this paper) rises over time as the mineral stock becomes depleted.

The E-source is assumed substitutable by a backstop technology (B-technology) which, although immediately available, has a higher cost than is presently economical (Nordhaus). It is further assumed that there exists a complete set of futures and contingency markets.

Solow analyzes the comparative dynamics and stability conditions as to how a change in the B-cost affects the E-source's capitalized value and price-output paths over time. "One imagines that resource companies keep a careful eye on the prospective costs associated with the backstop technology. Any laboratory success or failure that changes those prospective costs has instantaneous effects on the capital value of existing resource deposits, and on the current rate of production" (p. 5). For example, given a reduction in the B-cost, perfectly functioning forward and contingency markets would signal a reduction in the future and present price of the E-source, which would immediately have the dual effect of reducing the capitalized value of a unit of the E-source (i.e., the unit royalty, or scarcity rent) and speeding up the present and expected future output flow of the E-source as industry output flows moved down along the industry demand schedule. Solow writes that "if futures markets actually existed, we could probably accept the notion that their equilibrium configuration is stable . . ." (p. 6).

Net benefits are defined to consist of consumer surplus plus producer royalties, where royalties are explicitly taken to mean the flow of scarcity rent accruing to owners of the fixed mineral stock. For example, in figure 1, suppose that q_o represents the initial period output flow of uranium ore, the E-source which is used to produce electricity, and C_e is the unit cost of uranium extraction. Electricity also can be produced by a high-cost solar technology (the B-technology). Under the assumptions of this paper, q_o, and hence initial period price, p_o, and initial period unit royalties, $p_o - C_e$, are simultaneously determined by (a) the cost of solar-produced electricity, (b) the rate at which mineowners discount future unit royalties, (c) the total stock of uranium, and (d) the unit extraction cost of uranium, C_e. Total initial-period royalty flow is equal to the lower shaded area $p_o p'_o C'_e C_e$, while the total net initial-period benefit flow for output level q_o is equal to the shaded area, $C_e D p'_o C'_e$. The present value of the sum of such shaded areas over the life of the uranium industry is that industry's contribution to net benefits derived from energy production-consumption. The period-by-period flow of shaded net benefits, of course, would be substantially less after society switched its dependence to the relatively high-cost B-technology (not shown in figure 1).

A Basic Model of Net Benefits Measurement

Given the above assumptions and definitions, it has been shown (see Hotelling, Herfindahl, Peterson, Solow) that the mineral market's competitive equilibrium is characterized by marginal profits (unit royalties) which grow at

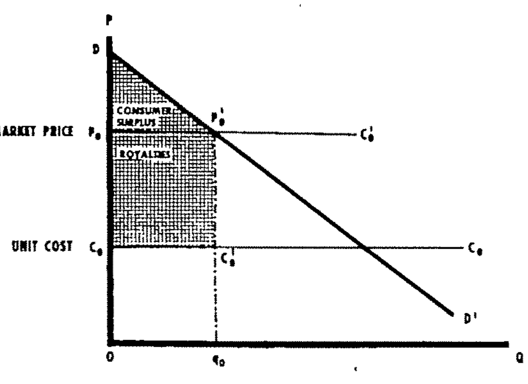


Figure 1. Total net benefit, consumer surplus, and royalties

the rate of discount. This result is based on the notion that mineowners are indifferent between marginal profits now, R_o, and marginal profits $R_o e^{rt}$ at some point, t, in the future.

The effect of a research-induced B-cost reduction on net social benefits can be explored via a system of four equations in four endogenous variables. Equation (1) is obtained in five steps.

First, note that market price is made up of unit extraction costs and unit royalties,

$$P(t) - C_e - R(t) = 0, \tag{1a}$$

where price, P, of the E-source (the E-price) at any point in time, t, equals unit extraction costs (the E-cost), C_e, plus unit royalties, R, at that time. Royalty payments are considered distinct from extraction costs because royalties are not an opportunity cost, and hence can be viewed as a net social benefit of production, whereas this is not the case with extraction costs.

Step two is simply the mathematical statement of the exhaustion constraint. Assuming absolute fixity of the total E-source stock, then

$$\int_0^T q(t)dt = K, \tag{1b}$$

where (1b) states that the flow of production, $q(t)$, summed over the period of production, 0 to T, is equal to the mineral stock, K. The implication is that the resource is exhausted at the switch point, time T. Clearly, one can think of many exhaustible resources which are no longer used but which have not been exhausted. Presumably, this is due to the rising costs of cumulative extraction. However, given this paper's assumptions, known deposits of the exhaustible resource with constant costs would be mined out before the switch was made to the backstop technology. For a similar description, see Solow (p. 5).

Next, the flow of production, $q(t)$, equal to the quantity demanded, is related to the market price via the (partial equilibrium) demand schedule, i.e.,

$$q(t) = q[p(t)], \quad q'(p) < 0, \tag{1c}$$

where $q[p(.)]$ is notation for the specific functional form of the demand curve for the E-source–B-technology energy commodity. Note that the term "supply curve" has not been mentioned. Recall that when a resource is exhaustible, the supply curve for the industry (and the firm) is not that of the traditional price taker. This, for two reasons. First, producer output at each point in time depends on the entire expected intertemporal price path. Thus, one cannot determine unambiguously how today's producer output flow will change given a change in today's price, for today's price does not change without future prices changing also. Second, analogously to a pure monopoly producer, a distinct price path over time is traced out by the industry depending on the manner in which the demand curve shifts. Clearly, the notion of a traditional industry supply curve does not describe the market for exhausible resources under this paper's assumptions.

Because unit royalties grow at the rate of compound interest in the competitive energy-mineral market under constant cost conditions,

$$R(t) - R_o e^{rt} = 0, \tag{1d}$$

where $R(t)$, the generalized functional notation for equilibrium unit royalties at a point in time, t, is initial-period royalties compounded to that period, i.e., $R_o e^{rt}$.

Equations (1a), (1b), (1c), and (1d) can be combined into a single equation, which in implicit form is

$$\int_0^T q(R_o e^{rt} + C_e)dt - K = 0. \tag{1}$$

Equation (1) shows that the total quantity of the resource used over its life is equal to its given supply, K. The expression $(R_o e^{rt} + C_e)$ is the E-source's price as an explicit function of time, t; $q(.)$ is the functional notation for quantity demanded as a function of the E-source's price.

A second equation states that at the time when production of the E-source ceases, i.e., at T (Nordhaus' "switch point"), its price will be equal to the unit B-cost,

$$R_o e^{rT} + C_e - C_b = 0, \tag{2}$$

where C_b is the unit B-cost. The formulation of this equation assumes that (a) the E-source has unit costs less than the B-technology; and (b) that any change in unit B-costs instantly results in a new equilibrium time path of extraction.

Next, the notion of net benefits is developed. Define the flow of net benefits at a given point in time as the flow of consumer-plus-producer surplus,[1] where producer surplus

[1] There is not universal agreement among economists that the constant money-income consumer surplus is an appropriate measure of efficiency benefits. Some feel that the Hicksian consumer

equals royalties as defined in this paper.[2] Total surplus for output flow q_o is equal to the shaded area in figure 1, because consumer surplus and royalties each are a social payoff in excess of the opportunity costs of extraction.

The total time-discounted value of net social benefits arising from the E-source, hereafter referred to as U_1 benefits, can be obtained by integrating net benefits over the life of the E-source, 0 to T, while continuously discounting at the real rate of time preference (assumed equal to the market rate of interest), r, i.e.,

$$(3) \quad \int_0^T ns[q(R_o e^{rt} + C_e)]e^{-rt}dt - U_1 = 0,$$

where $ns(.)$, compact functional notation for net surplus flow, equals the shaded area in figure 1, which is total willingness-to-pay less extraction costs for output flow, $q(.)$; and e^{-rt} is the discount factor applied to the flow of net benefits at ^{T} to make them commensurate at time zero. It should be emphasized that U_1 benefits are defined as the present value of total net benefits attributed solely to the use of the E-source. Benefits arising from the B-technology will be distinguished from those arising from the E-source, if only for the sake of analytical convenience. (Presumably, to the final buyer of energy, for example, electricity generated from coal is not distinct from solar-generated electricity.)

The fourth and final equation defines the present value of time-discounted net social benefits arising after the introduction of the B-technology. These benefits (U_2 benefits) consist of consumer surplus discounted from the switch point, T, to perpetuity, ∞ (because no producer surplus can exist given a constant long-run supply price). Mathematically, U_2 benefits are defined as

$$(4) \quad \int_T^\infty \{ns[q(C_b)] - q(C_b)(C_b - C_e)\}e^{-rt}\,dt - U_2 = 0;\ C_b - C_e > 0,$$

where $ns(.)$, as in equation (3), is the flow of net surplus for output level $q(C_b)$, and $q(C_b)$ is the output flow demanded at a B-cost, C_b. From $ns(.)$, must be subtracted $q(C_b)$ $(C_b - C_e)$, the royalty flow no longer received by E-source owners once the switch is made to the B-technology.

Note that equation (4) is written in such a way as to emphasize that producer surplus no longer exists when the economy switches to the B-technology. However, the reader can see that since U_2 is simply the time-discounted area under the demand curve and above the B-cost (C_b) supply price, equation (4) could also be written as

$$(4a) \quad \int_T^\infty \int_{Cb}^{pm} q(p)e^{-rt}dpdt - U_2 = 0,$$

where $q(p)$ is the demand function and p_m is the demand price that chokes consumption to zero. In either case, equation (4) or (4a) defines U_2 benefits as the discounted value of consumer surplus for a B-cost, C_b from the switch point, T, to perpetuity.

Equations (1) through (4) have been constructed so that equilibrium values can be determined for each of the following four endogenous variables: (a) U_1, total time-discounted net benefits from the E-source; (b) U_2, total time-discounted net benefits from the B-technology; (c) R_o, initial period royalties (and hence royalties and price) at all points in time; and (d) T, the switch point. Each of the four endogenous variables is thus indirectly a function of the following parameters: r, the interest rate; C_e, the per unit cost of the E-source; C_b, the per unit B-cost; K, the stock of the E-source.

Within the context of equations (1) through (4), recall that the purpose of this paper is to focus on the specific sensitivities, $\frac{\partial U_1}{\partial C_b}$ and $\frac{\partial U_2}{\partial C_b}$, i.e., the sensitivities of (the endogenously determined) U_1- and U_2-benefits to parametric shifts in the B-cost. Of course, the four equations could be used, if desired, to determine the sensitivity of all four endogenous variables to other parameters including, for example, the net benefits attributable to (a)

surplus is the correct measure. For example, Herfindahl and Kneese (p. 190) state that the area beneath the Marshallian demand curve is correct only when the income effects of actual payments, if they were made, is zero. For an alternative viewpoint, see Ward (1979). In addition, it is not altogether clear that public investments in energy cost reduction technology should worry about the loss of rents to present natural monopoly holders. This is a political question rather than a scientific calculation.

[2] Market demand price is assumed equal to marginal willingness-to-pay, and the unit cost of mineral extraction is assumed equal to marginal opportunity cost. That is, it is assumed that the entire net social payoff of energy production-consumption is captured between the relevant market demand and unit cost curves. This assumption is not entirely consistent with much of the conceptual foundation of cost-benefit analysis. The cost-benefit approach quantifies the net social benefits of resource reallocations under conditions where marginal social value diverges from the demand function, and/or marginal opportunity cost is not equal to private marginal costs.

research that reduces the E-costs, C_e, and (b) changes in the stock of the E-source.

The Implicit Function Theorem of mathematics (Chiang, pp. 198–240) allows one to solve directly for the required partial sensitivities. It is straightforward to show that they are as follows (derivations are available from the author):

$$\text{(7a)}\quad \frac{\partial U_1}{\partial C_b} = \frac{1}{|J|}\{ns[q(C_b)]e^{-rT} \int_0^T q'(R_0e^{rt} + C_e)e^{rt}dt - q(C_b) \int_0^T ns'(q)q'(R_0e^{rt} + C_e)dt\},$$

$$\text{(7b)}\quad \frac{\partial U_2}{\partial C_b} = -q(C_b)\frac{e^{-rT}}{r} - \frac{\partial T}{\partial C_b}\{ns[q(C_b)] - q(C_b)(C_b - C_e)\}e^{-rT}$$

where $|J| = \begin{vmatrix} \int_0^T q'(R_0e^{rt} + C_e)e^{rt}dt & e^{rT} \\ q(C_b) & rR_0e^{rT} \end{vmatrix}$,

and primes indicate partial derivations.

Examining the two sources of benefits, attention is directed first to (7b), $\frac{\partial U_2}{\partial C_b}$. According to (7b), the reduced C_b (B-cost) has two effects on U_2 benefits. The first term in (7b) says that the extra benefits of a unit B-cost reduction equals that B-cost reduction times the flow of consumption, $q(C_b)$, to which the reduced cost applies, multiplied by $\frac{1}{r}e^{-rT}$. This first term is the present value of the infinite stream of cost-savings for which receipt commences at the switch point, T. This term is simply the dynamic analogue, in differential form, of Lindner and Jarrett's static net benefit measure of a research-induced reduction in supply price.

The second term in (7b) is one which is unique to the intertemporal nature of the competitive mineral extraction process. This component of $\frac{\partial U_2}{\partial C_b}$ is the reduced waiting time for the switch point to occur, $\frac{\partial T}{\partial C_b}$, times the consumer surplus flow which energy consumers receive at the existing B-cost, where e^{-rT} discounts that increment of nearer-to-the-present surplus back to time zero from the switch point. This second component is a quantification of the notion that because the switch point itself is brought closer to the present resulting from the decreased B-cost, energy buyers receive their discounted B-technology consumer surplus at an earlier point in time would have been the case had the B-costs not fallen.

For example, suppose that under conditions of a relatively high B-cost, energy consumers could expect a potential undiscounted annual flow of \$100 in consumer surplus benefits after the switch to the B-technology. However, under conditions of a lower B-cost, consumers could expect to receive that annual flow of benefits "t" years earlier, due to the speeding up of the E-source's exhaustion. The second component of (7b) would then be (\$100t)e^{-rT}, which measures the discounted value of B-technology consumption benefits being brought "t" years closer to the present.

Thus, in summary, equation (7b), $\frac{\partial U_2}{\partial C_b}$, sums the two subcomponents of the gain in U_2 benefits attributable to a B-cost reduction. First, consumers receive the benefit of a future cost savings arising from the lower B-cost. This cost savings must be summed and discounted from the switch point to infinity. In addition, the decreased B-cost reduces the period of dependence on the E-source. The undiscounted consumer surplus which would have been received at the "initial" switch point, say thirty years from now, instead will be received at a point earlier in time, say twenty years from now, when the B-costs fall.

Equation (7b) has summarized two subcomponents of the net benefits attributable to a B-cost reduction. However, there is another more subtle term which should be included in the measure of net benefits. This term is summarized by $\frac{\partial U_1}{\partial C_b}$.

Examining equation (7a), observe the conditions which are sufficient to force $\frac{\partial U_1}{\partial C_b}$ to take on a value of zero, i.e., for U_1 to reach an extremum relative to changes in C_b. That condition is zero (E-source–B-technology) energy

consumption, $q[.] = 0$, at the switch point, T. This, of course, would only come about if the B-technology were uneconomical, in which case T would represent the terminal period of consumption. For a sufficiently uneconomical (high) B-cost, consumers would be forced back to the level of zero consumption on their demand curve, where both (*a*) the output flow, $q(C_b)$, and (*b*) net surplus flow, $ns(C_b)$ are necessarily zero. In this situation, both halves of (7a) take on a zero value which, given a nonzero denominator, is sufficient to yield a value of zero for $\frac{\partial U_1}{\partial C_b}$. (In all practicality, the point of zero consumption may never be reached.) What are the economic implications of equation (7a) taking on a zero value?

Recall that under this paper's assumptions, the competitive market allocates the exhaustible mineral over time in such a way that (*a*) unit royalties grow at the rate of compound interest, and (*b*) output flow at the switch point, T, is restricted just sufficiently for the E-source market price at T to equal the B-cost. Since the price of the E-source at T must equal the B-cost, (7a) says that if the B-cost is so high that consumption shrinks to zero at T, then $\frac{\partial U_1}{\partial C_b} = 0$, and the present value of net benefits from the E-source (U_1 benefits) reach an extremum. Is this extremum a maximum?

The following geometrical presentation shows that (*a*) U_1 benefits do reach a maximum when exponentially growing unit royalties are coupled with an output flow of zero at T, and (*b*) $\frac{\partial U_1}{\partial C_b}$ is greater than zero (i.e., falling B-costs reduce U_1 benefits) when the existing B-cost is low enough to be economical. (See the appendix for more rigorous proof using optimal control theory.)

Suppose that the expected time path of energy mineral output follows a pattern such that unit royalties, equal to marginal net benefits, i.e., price less marginal cost, grow at less than the rate of compound interest. If this is the case then clearly U_1 benefits can be increased by allocating less output flow to later periods and more to earlier periods. However, recalling that the magnitude of the B-cost directly affects which specific dynamic exponential growth path of unit royalties is actually tracked by the competitive market, the relevant question becomes: Do all output

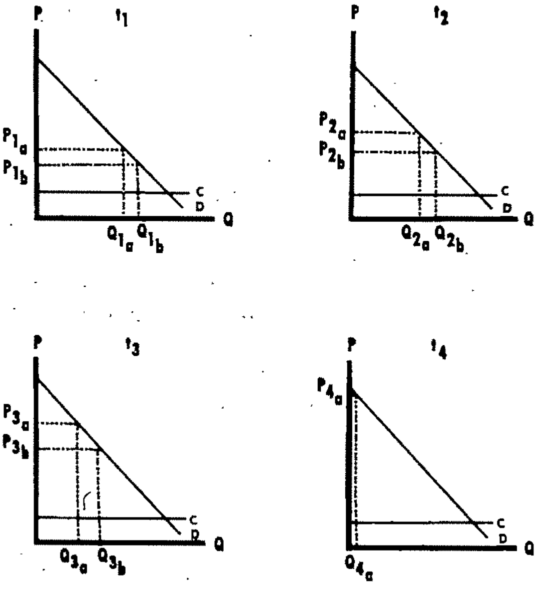


Figure 2. Two possible time paths of extraction which exactly exhaust a given supply of an energy mineral

paths where marginal net benefits grow exponentially bring about equal U_1 benefits?

In figure 2, panels $t_1 - t_4$, there are two time paths of mineral output shown, each of which yields exponentially rising unit royalties. In each panel, the demand curve is D and unit E-cost is C. The path with "*a*" subscripts shows output flow following the four-period time path of Q_{1_a} through Q_{4_a}, with unit royalties taking on the successive values of P_{1_a} (minus C) through P_{4_a} (minus C). Suppose that when path "*a*" is followed, the fixed supply of the mineral is exhausted in four periods and the B-cost (C_b) is sufficiently high so that the final period price of the E-source, P_{4_a}, is high enough whereby one unit, the last remaining unit in the ground, is demanded.

Next, consider an alternative time path of extraction with "*b*" subscripts. Call this path "*b*". Assume that path "*b*" would be the equilibrium path followed when the B-cost, C_b is equal to P_{3_b}. Unit royalties still grow at an exponential rate, but because of the lower B-cost, royalties are lower in each period and the output flow of the E-source is higher, corresponding to a lower price in each production period. Assume that this "*b*" path leads to exhaustion in three periods.

Focusing attention on panel t_3, if the marginal unit of output represented by Q_{3_b} were shifted out of period three into period four,

then period three's social cost of the output in foregone net benefits is P_{3_b} (minus C). The gain of that output increment measured in period four's net benefits, when discounted by one period, equals P_{3_d} (minus C), [P_{4_a} (C), discounted by one period] which is larger than P_{3_b} (minus C). Clearly, that incremental shift increases discounted net benefits, which means that a path such as "b" does not yield maximum U_1 benefits. Thus, for U_1 benefits to be at a maximum, the marginal unit of output in the last period must be such that (a) when discounted, it yields marginal net benefits in the last period equal to those of previous periods, and (b) price minus unit cost is at a maximum. (More generally, marginal benefits equals average benefits. See the appendix for a proof.)

From the results of the geometrical presentation in figure 2, it can be seen that if the B-cost is less than the choke price, P_{4_a}, then under competitive conditions, U_1 benefits fail to reach a maximum. Extending the above reasoning, it can be seen that further reductions in the B-cost actually reduce U_1 benefits. Therefore, $\frac{\partial U_1}{\partial C_b}$, as defined by (7a) is positive; reductions in the B-cost actually reduce U_1 benefits, when the existing B-technology is sufficiently cheap to allow positive consumptions of B-source-produced energy.

What, then, are the economic implications of the net benefit measurements of (7a) and (7b)? First, when the cost of the backstop technology declines, society stands to benefit substantially due to lower energy prices from that day (time zero) onward. Second, however, this reduced B-cost will have the effect of speeding up the extraction rate of the E-source, which speedup tends to lessen the present value of U_1 benefits that will be obtained from that source. Thus, the benefits lost on the E-source resulting from the B-cost reduction, $\frac{\partial U_1}{\partial C_b}$, must be deducted from the otherwise positive benefits of the falling B-cost, $\frac{\partial U_2}{\partial C_b}$, to obtain total net social benefits attributable to research which lowers the B-cost.

Summary and Conclusions

This paper has developed a conceptual measure of net social benefits attributable to increased energy research, a measure developed by establishing an analytical linkage between the literature of (a) social cost-benefit analysis, and (b) the economics of exhaustible resources. There are three major such sources of welfare change identified in this paper. First, society receives a cost savings brought about by the backstop cost reduction which should be discounted from the point at which society switches to backstop technology into perpetuity. Second, because the switch point itself is reduced by the falling backstop cost, energy consumers receive a consumer surplus benefit from the backstop technology at an earlier point in time. That consumer surplus must be summed and discounted across the extra increment of time by which the switch point is reduced. Third, the extraction rate of the exhaustible mineral is sped up due to the reduced backstop cost, which reduces the present value of the net social payoff receivable from the exhaustible resource when considered in isolation. Although it is clear that a research-induced reduction in the backstop cost confers immense positive net benefits on an energy-dependent society, it is necessary to evaluate all three sources of net benefits. Particularly if the third source is ignored, the net benefits of energy research can be overstated.

Limitations and Needs for Further Research

This paper's net benefit measure of energy research has been based on several simplifying assumptions. Clearly, it would be desirable if a similar measure could be developed under a more realistic set of assumptions, and hence this study points to the need for further research. One wonders about the limitations of the assumptions, particularly as they affect the third source of net benefits, i.e., the loss in net social payoff of the exhaustible resource due to the cost reduction in the backstop technology. This third source is shown to bring about a negative contribution to benefits because of the assumption that a fixed stock of homogeneous resource with constant costs will be extracted over time, regardless of the cost of energy provision via the backstop technology. It is the speeding up of the extraction from this given stock which reduces the present value of benefits derivable from that stock. Perhaps under a more general set of assumptions, further work may show that the sign of this third component of net benefits is reversed. In spite of simplifying assumptions, this paper constructs a net benefits measure of energy re-

search that establishes a linkage between the cost-benefit literature and a received theory of exhaustible resources. Therefore, the present paper provides a point of departure for quantifying the net social value of energy research.

[*Received November 1978; revision accepted April 1979.*]

References

Arndt, Thomas M., and Vernon W. Ruttan. *Resource Allocation and Productivity in National and International Agricultural Research.* New York: Agr. Develop. Council Seminar Rep., Sept. 1975.

Chiang, Alpha. *Fundamental Methods of Mathematical Economics.* New York: McGraw-Hill Book Co., 1974.

Currie, John Martin, John A. Murphy, and Andrew Schmitz. "The Concept of Economic Surplus and Its Use in Economic Analysis." *Econ. J.* 81(1971):741–99.

Evenson, Robert E., and Yoav Kislev. *Agricultural Research and Productivity.* New Haven, Conn.: Yale University Press, 1975.

Goldsmith, Oliver S. "Market Allocation of Exhaustive Resources." *J. Polit. Econ.* 82(1974):1035–40.

Griliches, Zvi. "Research Costs and Social Returns: Hybrid Corn and Related Innovations." *J. Polit. Econ.* 66(1958):419–31.

Hadley, G., and M. C. Kemp. *Variational Methods in Economics.* Amsterdam: North-Holland Publishing Co., 1971.

Herfindahl, Orris. "Depletion and Economic Theory." *Extractive Resources and Taxation,* ed. Mason Gaffney. Madison: University of Wisconsin Press, 1967.

Herfindahl, O. C., and A. U. Kneese. *Economic Theory of Natural Resources.* Columbus, Ohio: Resources for the Future, 1974.

Hotelling, Harold. "The Economics of Exhaustible Resources." *J. Polit. Econ.* 39(1931):137–75.

Lindner, R. K., and F. G. Jarrett. "Supply Shifts and the Size of Research Benefits." *Amer. J. Agr. Econ.* 60(1978):48–58.

Mishan, E. J. *Cost-Benefit Analysis, New and Expanded Edition.* New York: Praeger Publishers, 1976.

Nordhaus, William. "The Allocation of Energy Resources." *Brookings Papers on Economic Activity.* Washington, D.C., The Brookings Institution, 1973.

Peterson, F. M. "The Theory of Exhaustible Natural Resources: A Classical Variational Approach." Ph.D. thesis, Princeton University, 1972.

Solow, R. M. "The Economics of Resources or the Resources of Economics." *Amer. Econ. Rev. Papers and Proceedings* 64(1974):1–14.

Ward, Frank A. "The Marshallian Consumer Surplus as an Appropriate Measure of Welfare Change." Unpublished manuscript, New Mexico State University, Jan. 1979.

———. "The Welfare Effects of a Market Allocation of an Exhaustible Resource." Ph.D. thesis, Colorado State University, 1977.

Weinstein, H. C., and R. J. Zeckhauser. "Optimal Consumption of Depletable Resources." *Quart. J. Econ.* 89(1975):370–92.

Appendix

Necessary Conditions for U_1 *To Be a Maximum*

As an alternative way of seeing that zero terminal-period consumption is required for the net U_1 benefits to be maximized, let us recast the net U_1 benefits measure in terms of a control-theoretic formulation, where, according to the assumptions of this paper, it is desired to choose the time path of mineral extraction which makes U_1 a maximum, subject to the constraint of a fixed total mineral stock. The terminal period of production, T, is a decision variable. The problem then becomes

$$(A_1) \qquad \text{Max } U_1 = \int_0^T \{ns[q(t)]e^{-rt} - \lambda[q(t)]\}dt,$$

where all variables are defined as before, with the exception of the added undetermined Lagrangian multiplier, λ, reflecting the constraint of the fixed total stock of the mineral, K.

Note that the solution to the control theoretic problem picks the time path of mineral flow which maximized U_1 benefits (subject to the mineral stock constraint), whereas the comparative statics approach taken in the body of this paper is that of determining the marginal effect on U_1 benefits of several alternative parametric shifts, based on an output path explicitly defined by a set of competitive assumptions. Thus, the control approach treats $q(t)$ and T, respectively, as (a) an unknown function of time, and (b) an unknown terminal time period, to be determined by the optimal control solution, whereas the comparative static approach defines $q(t)$ and T as known functions which are explicitly determined by the structural competitive equations (1) through (4).

The solution of the control problem comes from the Euler equation and transversality (end-point) condition (Hadley and Kemp). They are, respectively, given by (A-2) and (A-3).

$$(A_2) \qquad ns'(q)e^{-rt} = \lambda,$$

$$(A_3) \qquad \frac{ns[q(T)]}{q(T)} = \lambda.$$

Equations (9) and (10), respectively, say that in order for the time path of extraction to yield maximum U_1 benefits, (a) the discounted marginal net benefit flow, $ns'(q)$ should be equal in all periods; and (b) in the terminal production period, the marginal net benefits flow should equal the flow of average net benefits, $ns[q(T)]/q(T)$. Given the assumptions of this paper, this means that unit royalties should grow at the rate of compound interest and terminal-period output flow should be zero, as marginal and average net benefits are equal only at a zero output.

Notes

Canadian Farm and Nonfarm Family Incomes

R. Paul Shaw

Analysis of the level and distribution of economic well-being in North American agriculture is, without doubt, underdeveloped and fraught with ambiguity. Bawden refers to this situation as "the neglected human factor" (p. 879). It stems from censuses of agriculture that are typically enterprise-oriented, problems of monitoring self-employment incomes, incomplete income measurement, and inadequate information on the increasing importance of off-farm work in the farm family income equation.

In Canada, the paucity of quantitative studies on the subject is highly visible. Examples of the few and far between include Fitzpatrick's regional analysis of farm family income based on a 1958 farm survey; a Federal Task Force on Agriculture evaluation of the low income problem using limited data on farm sales and capital value; Gellner and Davey's study of incomes using aggregate tax data; McClutchy and Campbell's estimates of "farm family real income," using the questionable 1972 Agriculture Enumerative Survey; and Kulshreshtha's 1967 measurement of farm:nonfarm incomes in historical perspective. Most of these studies are comparable in neither methodology nor empirical coverage. Absence of information on returns to off-farm work is particularly conspicuous. With the exception of Kulshreshtha's work, little attempt has been made to evaluate alternative farm:nonfarm income measures, or the extent to which their viability depends on the context in which they are being used.

These shortcomings prompted a complete linkage of Canada's 1971 Censuses of Agriculture and Population, resulting in a unique data base with a wealth of income data. Some 365,000 farm enterprise questionnaires (with 199 questions) have been computer matched with independently enumerated Census of Population questionnaires for the respective farm households. One-third of the latter have been enumerated on a detailed sample basis. They contain approximately sixteen detailed income and employment-related questions and cover all members of the census farm household. The linkage was designed and performed under the direction of the author. For details see Shaw (1971, 1979a) and Freeman. Income questions on the 1971 Census of Population pertain to 1970. Total family cash income is the sum of all income earned by family members from wages and salaries, net farm self-employment, nonfarm self-employment, transfer payments, interest, rent, and other.

This linkage commences a new decennial series with the advantage that income coverage for farm and nonfarm families will stem from the same census methodology and will pertain to the same time period. We draw on this improved source (*a*) to place disparities in farm:urban incomes in Canada in clearer perspective, and (*b*) to single out the incredible impact that off-farm work is having on reducing disparities.

R. Paul Shaw has been affiliated with the University of British Columbia and International Labour Organization.

Measuring Proximity to Parity

Needless to say, comparison of incomes from largely self-employment contexts with those of wage and salary contexts faces many hazards. For example, the flow of income in self-employment farming is more susceptible to wide fluctuations (e.g., depending on weather, international trade), farm and nonfarm incomes should be measured in cash as well as "in kind," reported incomes may be biased downwards due to delayed consumption of current income (i.e., toward building up capital stock), psychic or nonpecuniary returns may be higher in rural-farm contexts, etc. In other terms, the 1971 agriculture-population linkage data represent a sound point of departure to which various refinements must be made.

In table 1, column 3, various farm-urban income ratios are summarized for Canada; table 2 gives a corresponding set of ratios for provinces. Rows 1–3 relate to individuals. In many respects, these ratios represent the standard approach to measuring disparities in economic well-being. At the Canada level, comparison of mean farm:urban per capita incomes (from all sources) implies a ratio of only .50 (table 1, row 1). The farm per capita gini coefficient is more than 1.5 times that of the urban sector. The proportion of the population in rural farm areas falling below Canada's "low level income cut-offs" or poverty lines, is more than double that of the population in urban areas. The "low level income cut-offs," based on expenditure data from Statistics Canada's family expenditure survey (1973a) specific to place of residence are (*a*) approximately $4,650 for an "average" urban family of 3–3.5 persons, for 1970, and (*b*) approximately $4,150 for an "average" rural farm family of 4–4.5 persons in 1970.

According to table 2, col. 1, the provincial per

Table 1. Intersectoral Income Comparisons: Canada, 1970

Measure	Farm[a] (1)	Urban[b] (2)	Ratio (1)/(2) (3)
	-------- $ --------		
Individuals: cash income			
1. Per capita income	1,500	3,000	.50
2. Gini coefficient	.45	.29	1.55
3. % below "cut-offs"	37	18	2.05
Families: cash + "in kind"			
4. Cash $	6,935	10,300	.67
5. Cash $ + "in kind"[c]	8,498	11,069	.77
6. Adj. for "wheat loss" to (5)	8,758	11,069	.79
Families: stock + flow (Y^*)	(FY^*)	(UY^*)	
7. Value of Y^*	11,316	11,644	.97
Avg. capital value[d]	66,200	17,646	
Avg. debt[e]	12,209	3,277	
Avg. rate of return[f]	.06	.06	
Avg. life expectancy[g]	69	70	
Avg. age of family head	49	45	
Families: cash $ + "in kind" by major or largest source of income			
8. Farm self-employment	6,838	11,069	.62
9. Wages and salaries	10,363	11,069	.94
Families: Y^* by major source			
10. Farm self-employment	9,029	11,644	.78
11. Wages and salaries	12,956	11,644	1.11

[a] Unless otherwise stated, data are from Statistics Canada, Agriculture-Population Linkage, unpublished tabulations.
[b] Unless otherwise stated, data are from Statistics Canada, 1971 Census of Population, unpublished tabulations.
[c] Income in kind for farm families was derived from Statistics Canada 1973c; for urban families, see footnote 1.
[d] For urban families, average capital value is represented by average total family assets, including value of owned homes.
[e] Statistics Canada 1973b.
[f] See Jenkins.
[g] See Statistics Canada 1974.

capita ratios of farm to urban incomes (from all sources) are as low as .42 to .45 for Manitoba and Alberta. Ratios of farm to urban population below the "low level income cut-offs" are often in excess of 2 (col. 3). In almost all cases, these national and provincial ratios imply the usual; incomes in self-

Table 2. Intersectoral Income Comparisons, Canada and Provinces, 1970

Area	Farm/Urban Ratios Specific to Individuals: Per Capita (1)	Gini Coefficient (2)	% Below Cut-Offs (3)	Farm/Urban Ratios Specific to Families: Cash + $ "In Kind" (4)	Wheat Adjusted to (4) (5)	FY^*/UY^* (6)	FY^*/Avg. UY^* for Canada (7)	Farm[a]/UY (8)	$W + S$[b]/UY (9)
Canada	.50	1.55	2.05	.77	.79	.97	.97	.62	.94
Newfoundland	.60	1.32	1.38	.84	.84		.73	.69	.99
Prince Edward Island	.56	1.31	1.58	.77	.77	.99	.74	.69	.91
Nova Scotia	.52	1.37	1.42	.81	.81		.85	.67	.90
New Brunswick	.50	1.39	1.72	.76	.76		.77	.61	.89
Quebec	.49	1.39	2.15	.89	.89	.91	.83	.64	.88
Ontario	.51	1.61	1.86	.96	.96	1.24	1.20	.78	1.09
Manitoba	.42	1.48	2.42	.63	.69		.82	.52	.80
Saskatchewan	.49	1.52	1.83	.70	.76	.99	.89	.60	.91
Alberta	.45	1.60	2.35	.72	.77		1.05	.58	.91
British Columbia	.58	1.60	1.17	1.05	1.05	1.35	1.36	.86	1.15

[a] The numerator of this ratio is "total family income of those farm families reporting farm self-employment as their major or largest source of income."
[b] The numerator of this ratio is "total family income of those farm families reporting wages and salaries as their major or largest source of income."

employment agriculture lag far behind those of the urban sector.

The first set of refinements acknowledges that (*a*) families, not individuals, are the major consumptive units in Canadian society, (*b*) "income in kind" is likely to be a more important source of nonpecuniary return in rural farm than urban contexts, and (*c*) stock must be taken of unusual fluctuations in farm productivity, sales, etc. With respect to the latter point, wheat is by far Canada's leading crop; and it is of some importance that declining exports between 1965–68 resulted in (*a*) an accumulation of unsold stocks, (*b*) voluntary reduction of wheat plantings by about 15% in 1969–70, and (*c*) a one-year federal scheme to remove up to 22 million acres of prairie land from wheat production in 1970. While producer incomes were compensated somewhat by government aids promoting shifts into production of barley, forage, oilseeds, and livestock, the fact remains that total 1970 net farm income in Canada's farm sector was about 14% less than the 1961–71 average (Shaw 1977).

Significance of the considerations above is reflected in table 1, rows 4–6. The farm:urban family ratio is .67, or .17 points higher than the per capita ratio. The difference is attributable to larger family size in farm areas of about 4.5 persons, on average, compared with 3.5 for urban areas. Adjustments for "income in kind" favors farm families with $1,563, on average, compared with $769 for urban families. In farm areas, "income in kind" constitutes the value of consumption of home-grown food, wool, and woodlot products, plus an imputed rental value of owner-occupied farm dwellings; in urban areas it constitutes an imputed rental value of owner-occupied urban dwellings.[1] Finally, the adjustment for the "wheat problem" raises the ratio another .02 points to .79. The "wheat adjustment" for the average Canada ratio was made by increasing the share of the farm family income from farming per se by 14%. At the provincial level, the adjustment was made solely among Canada's major wheat producers where returns to farming were augmented to offset respective provincial losses. In defense of these adjustments, see Shaw (1977).

The importance of these adjustments is particularly apparent among provinces. For example, in table 2, column 5, the intersectoral status of Canada's principal wheat producers, Manitoba, Saskatchewan, and Alberta has improved by a factor of 1.5 over the per capita ratios in column 1. Incomes of farm families are now close to par in Ontario and actually exceed urban levels in British Columbia.

The second set of refinements addresses the tendency to delay consumption of current income for purposes of building up equity. It is well-known that capital deepening is particularly prevalent among self-employed farmers, and that the nature of tax reporting and allowances in agriculture is particularly conducive to such behavior (Shaw 1977). As a result, reported pecuniary returns to farm labor and capital may be biased downwards disproportionately.

A crude way of incorporating this consideration is to estimate a combined stock and flow of average yearly income for both farm and urban families. The stock consists of a yearly annuity (A) on net wealth (NW). In the case of farm families, then, the combined stock and flow (FY^*) can be estimated as follows:

$$FY^* = Y_{nf}^{o} + Y_{nf}^{m} + A, \tag{1.1}$$

$$A = NW\{r/[1 - (1 - r)^{-n}]\},\ n = e_x^{o} - a, \tag{1.2}$$

$$NW = K - D, \tag{1.3}$$

where Y_{nf} is nonfarm income, o is operator, m is family members, K is total value of farm capital, e_x^{o} is age-specific life expectancy of the family head. K includes land, buildings, machinery, and livestock. Average rates of return on capital in agriculture and manufacturing (r) were derived from Jenkins. Life expectancy and age data were obtained from Statistics Canada (1974). Net wealth (NW) was derived using average farm debt specific to province, obtained in Bank of Canada and Rust and elaborated in Shaw (1977).

To avoid double counting returns to farm capital value, income from farming is not included in equation (1.1) (Weisbrod and Hansen, Carlin and Reinsel). For urban families, NW corresponds to the total asset holdings of the family (K) minus average family debt (D)—asset and debt profiles for urban families were obtained from Statistics Canada (1973b). The flow of family income corresponds to average non-self-employment income of all family members.

Assuming that household welfare can be represented as a function of expected total lifetime resources, the annuity on lifetime resources in FY^* and UY^* represents a behavioral definition of current economic welfare. As long as expected income in all future periods equals current income, then the value of FY^* and UY^* will serve as an accurate estimator of this annuity. Admittedly, these measures may understate (*a*) the current welfare of households whose incomes are expected to rise, and (*b*) the relative welfare of households employed in sectors with higher levels of on-the-job training and greater experience premiums. Further, FY^* and UY^* might understate the welfare of younger

[1] Gross estimates of "income in kind" to farmers are provided for Canada and the provinces in Statistics Canada (1973c, p. 6). These figures have been divided by the respective number of farm households to estimate average figures on a family basis. As for urban families, Statistics Canada (1976, p. 278) estimates a value for "gross imputed rent" of owner-occupied dwellings, but this is published for all families at the national level only. Statistics Canada has supplied me with their estimation procedure towards deriving figures specific to urban areas at the provincial level. Essentially, Statistics Canada multiplies the average yearly rent of urban rented dwellings by the number of urban owner-occupied dwellings (adjusted for space) and divides the product by the total number of urban dwellings. Data for this exercise were obtained from Statistics Canada (1975).

households relative to that of older households to the extent that age-earnings profiles would tend toward convexivity. Herein lies the crudeness of our measures. At best, we can assume that these problems will tend to cancel one another out as we are interested primarily in ratios of average FY^*/UY^*.

Our adjustment for equity holdings among farm and urban families results in a FY^*/UY^* ratio near parity (table 1, row 7). Table 2, column 6, reveals that Ontario and British Columbia are considerably in excess of parity. Only in Quebec is the relative income situation discernably in favor of Quebec's urban sector. Two of the ratios in table 2, column 6 are grouped, as asset and debt data for the calculation of UY^* were limited to four regions only (Ontario, British Columbia, Atlantic provinces, and the prairies).

If we also acknowledge that both farm and nonfarm incomes vary considerably between Canadian provinces, then disparities in provincial FY^* are more evident. Table 2, column 7 suggests that Newfoundland, Prince Edward Island, and New Brunswick are on the low end of the "standardized scale" whereas Ontario, British Columbia, and Alberta are in excess of parity.

Our final set of refinements concerns the rising trend of off-farm work in North American agriculture. In many respects this trend is a blessing in North America's rural/urban adjustment process, as it serves to relax the dilemma of "forced" occupational and residential relocation in instances where returns to farming per se are inadequate (Shaw 1979c). As such, we propose that it is working to boost systematically the relative income situation of an increasingly large share of Canadian farm families (more on this later).

Major or largest source of income during the year is used to gauge the influence of off-farm work on the relative income situation of farm versus urban families. Census-classified farm families are disaggregated into two principal subgroups. Those with "farm self-employment income" as their major source constitute 43.9% of Canadian census farm families. Those with "wage and salary income" as their major source constitute 41.2%. While this split may seem to imply that bonafide farm families fall into the former group, it is important to note that such a conclusion does not emerge when farm enterprise characteristics of the two groups are compared (Shaw 1979a chap. 4).

Clearly, table 1, rows 8–9, reveals that farm families in the wage and salary group are considerably better off than those in the farm self-employment group. In fact, the provincial comparisions in table 2, column 9 reveal that farm families with wages and salaries as their major source of income are better off than their urban counterparts in Ontario and British Columbia. A similar impression emerges when our stock and flow measure (FY^*) is derived specific to each subgroup. This calculation is made at the national level only (table 1, rows 10–11). In deriving these measures, we found that the annuity on net wealth of the "farm" group was about 1.5 times that of the "wage and salary group." However, the off-farm income differential between the two groups, $Y_{nf}^{o} + Y_{nf}^{m}$ in equation (1.1), is such that FY^* of the wage and salary group outshines that of the farm group by almost $4,000. It is a full 11% larger than for urban families (UY^*).

Summing up, the various comparisons above stand in sharp contrast to the popular belief that problems of low or inadequate incomes go hand in hand with rural farm living. In many respects, they give credence to the old suspicion that "farmers seem to live poor, die rich" by showing that the average relative income and equity situation of Canadian farm families appears to be close to parity, especially among those with access to off-farm employment opportunities. While these findings are clearly relevant to equity goals in Canada, let us focus specifically on the outstanding contribution of off-farm work in view of its relevance to the two most recurrent policy concerns in Canadian agriculture—"to help low income farm families make a better living" and "to protect farmers against income instability."

Focus on Off-Farm Work

From a historical perspective, there can be little doubt that the improvement in the relative income situation of North American farm families is, in part, attributable to the increased prevalence of off-farm work (Bollman, Gunn, Schuh, Schultz). Between 1940–70, the author found that the contribution of off-farm wages and salaries to total farm family incomes in Canada increased from approximately 12% to 59%. During the same period, the ratio of total farm family income to urban family income (adjusted for income in kind) increased from approximately .57–.76. Corresponding figures for the United States between 1949–69 are 29–52% and .60–.77, respectively (Shaw 1979c).

The impact of off-farm earnings on the distribution of total employment income in Canada has been such that without it, the proportion of "self-employed farm operators" in the "poverty" category would be about 1.5 times its present size (Shaw 1979a, p. 129). Almost identical results were reported for the United States by Larson.

We already have shown that families reporting wages and salaries as their major source of income have considerably higher average incomes than those largely reliant on self-employment farming. In most cases, heads of families in the former category are part-time farmers and multiple jobholders. These farm operators tend to work a large part of their work-year off the farm at occupations requiring nonfarm skills. In Canada, they accounted for almost 30% of Canada's 365,000 farm operators in 1970. They worked, on average, 150 days off their farms as construction workers (24%), in transport (17%), in machine product fabrication (17%), sales

(10%), processing (9%), clerical (6%), as managers, administrators, and teachers (8%), and in other primary jobs (9%).

While part-time farmers and multiple jobholders often own relatively small-scale farms, it is not always appropriate to assume that these farms go hand in hand with marginal farming or that multiple job holding represents an initial stage of farm abandonment. Rather, off-farm work, and especially multiple job holding, represents an important source of revenue for capital deepening and reduces vulnerability of farm families to wide swings in farm prices and net farm income. It is also an important means by which returns to education, and, therefore, total employment income, can be augmented (Shaw 1979b).

Toward evaluating the relationship between off-farm work and income disparities more rigorously, we regress "% of part-time farmers" (*P*) in each of 252 census divisions (*CD*'s) on three income measures. These are (*a*) the ratio of average cash income of farm families to urban families in each *CD* (*FFY/UFY*), (*b*) the proportion of farm families below Canada's "low level income cut-offs" (*% POOR*), and (*c*) gini coefficients of concentration (*G*) for farm families per se. As a check on our representation of part-time farmers and multiple job holding, we also have regressed the three income measures against "average number of days worked off-farm" (*D*) by census farm operators/family heads in the *CD*.

In each regression, value of farm capital (*K*) has been included as a control variable. Farm capital value (*K*) is known to be positively correlated with almost all farm magnitude variables, net farm income, etc. Its place in explaining variations in each of the three income measures is relatively straightforward; an increase in *K* will result in an increase in *FFY/UFY*, a decline in *%POOR*, and an increase in the gini coefficient of concentration (*G*). That is, higher *K* will positively influence net farm income and, therefore, *FFY*. The higher the value of *K*, net farm income, and *FFY*, the smaller the proportion of farm families with incomes below the poverty lines. In contrast, as capital continues to be distributed unequally among Canadian farm families and as this inequality perpetuates income inequality, *K* is hypothesized to be positively related to *G*.

We also include a dummy variable (*DUM*) to represent proximity to large urban labor markets. *DUM* has been represented as 2 if the census division includes, or is adjacent to, a census division with an urban center of 25,000+ inhabitants (1, otherwise). Unfortunately, this variable does not have an unambiguous interpretation. For example, it tends to represent greater opportunities for off-farm work per se, and thus tends to be multicollinear with the effect of *P* on *FFY*. Our principal interest in *DUM* is to control for the possibility that jobs located in closer proximity to urban centers offer higher rates of remuneration. Thus, while multiple jobholding may have a positive effect on *FFY* via days worked off-farm, location of the job in close proximity to an urban area may add an additional wage effect.

Results, summarized in table 3, convey the following: (*a*) According to equations (1)–(3), prevalence of part-time farming or multiple job holding (*P*) boosts the ratio of farm family to urban family income, reduces the proportion of farm families below Canada's poverty line (*% POOR*), and reduces inequalities in the distribution of income

Table 3. Regression Coefficients: Off-Farm Work and Select Income Measures

EQ.	Dependent Variable	Intercept	Independent Variables			R^{2a}	*F* ratio
1.	*FFY/UFY*	.29276	+.00377 *P*	+.000161 *K*	+.0834 *DUM*	.353	46.76
		(st. error)	(.00047)	(.000026)	(.0156)		
		(*t* ratios)	(8.01)	(6.21)	(5.35)		
2.	*% POOR*	73.827	−.3953 *P*	−.01817 *K*	−5.30 *DUM*	.456	71.20
			(.037)	(.0020)	(1.22)		
			(10.73)	(8.90)	(4.35)		
3.	*G*	.5065	−.00164 *P*	+.00003 *K*	−.00686 *DUM*	.260	30.50
			(.00019)	(.000011)	(.00654)		
			(8.32)	(2.76)	(1.05)		
4.	*FFY/UFY*	.3930	+.00178 *D*	+.000122 *K*	+.0900 *DUM*	.294	35.80
			(.00029)	(.000026)	(.01624)		
			(6.14)	(4.61)	(5.54)		
5.	*% POOR*	68.22	−.2622 *D*	−.0144 *K*	−5.754 *DUM*	.535	97.50
			(.0200)	(.0018)	(1.22)		
			(13.30)	(7.86)	(5.13)		
6.	*G*	.4668	−.00084 *D*	+.000047 *K*	−.00954 *DUM*	.210	23.33
			(.00012)	(.000011)	(.00673)		
			(7.00)	(4.26)	(1.42)		

[a] *FFY/UFY* is average farm family total income per census division divided by the average urban family income of the same census division; *% POOR* is percentage of families in the census division with per capita family income less than the provincial "low level income cut-offs"; *G* is gini coefficient of concentration.

among farm families. Similar results are found in equations (4)–(6), where (P) is replaced by days of off-farm work (D).

(b) Higher levels of farm capital value also contribute to a higher ratio of farm family to urban family incomes, and is related negatively to the incidence of poverty. However, in contrast to the distributional benefits of part-time farming or multiple job holding, higher values of farm capital (K) contribute to inequalities.

(c) In equations (1) and (2), proximity to urban areas (DUM) has a significant positive effect on the farm to urban family income ratio, and is negatively associated with the incidence of "poverty." While this variable does not have an unambiguous interpretation, as noted above, it suggests that off-farm work is not equally available across geographical units, and/or that the off-farm opportunity wage differs between regions also.

(d) Of the three variables considered, part-time farming (P) or days of off-farm work (D) are most significantly related to improvements in the various income measures. While neither R^2 values, nor point elasticities are large, i.e., elasticities of about .4 to .6 for P in equations (1)–(3), they are extremely significant in view of (i) the slow pace of improvement in measures of farm family income over the last few decades (especially income inequalities), (ii) the fact that point elasticities for P exceed those of farm capital value, and (iii) the fact that part-time farming or multiple jobholding, which represents an important structural adjustment to changing conditions in Canadian agriculture, has gone largely unaided policywise.

Conclusion

Previous to the 1971 agriculture-population linkage, farm families just about everywhere appeared to be in need of some kind of income assistance. This impression certainly hampered effectiveness of Canada's Small Farm Development Program because the extent and whereabouts of poverty among family units was virtually impossible to measure (Shaw 1979a). In view of the findings here, however, farm families in some provinces are better off, on average, than their urban counterparts. This is certainly relevant to rethinking geographical targets for Canadian income policy, particularly as it applies to transfer payments and income supplements to farm families in Ontario and British Columbia versus, say, Manitoba and Quebec.

The fact that a large and growing share of farm families have access to off-farm employment which works to boost family incomes and accumulated wealth also is clearly relevant to rethinking population targets for income policy. Our estimates suggest that those in the "part-time" farm subgroup are considerably better off, on average, than their "full-time" counterparts. While both groups may be bonafide farmers, presence of off-farm income earning opportunities among the former group certainly will cushion inadequate farm incomes during difficult times and could be used to screen recipients of grants-in-aid.

With respect to boosting incomes of full-time farmers or reducing disparities in the distribution of income, policies designed to increase access to off-farm employment are clearly relevant. Indeed, our findings marry well with those of numerous surveys that have revealed that off-farm work is an important and growing contributor to farm family income at various stages of development. For example, off-farm work is prevalent among 47% of U.S. farm families, 72% in Japan, 59% in Poland, 40% in Taiwan, 25% in Korea, 30% in Lebanon, 30% in Algeria, and 50% in Kenya (Benachenon, Huffman, Kenya Central Bureau of Statistics, Larsen and Hu, Szenberg). The concentration of off-farm work and multiple jobholding among small-scale farms in the United States, Algeria, Malawi, and Central Java is particularly important as it has been shown to have an important bearing on equalizing the distribution of employment earnings (Benachenon, Chipeta, Soejono).

Finally, off-farm work is clearly relevant to problems of income instability. It tends to reduce vulnerability of farmers to wide swings in farm prices and net farm income, and aids beginners or small-scale farmers by providing a more even income flow for capital deepening or debt servicing. While rural development policy in Canada has sought to encourage alternative employment opportunities in rural areas, it is also true that off-farm work and multiple job holding per se have gone largely neglected by Canadian policy makers.

[Received July 1978; revision accepted April 1979.]

References

Bank of Canada. *Bank of Canada Review*. Ottawa, 1973.

Bawden, D. L. "The Neglected Human Factor." *Amer. J. Agr. Econ.* 55(1973):879–88.

Benachenon, A. "Politiques Rurales et Migrations Internes en Algerie." Mimeographed. Geneva: International Labour Organization, 1978.

Bollman, R. "Off-Farm Work by Operators of Canadian Census Farms." *Can. Farm Econ.* 8(1973):1–5.

Carlin, T. A., and E. I. Reinsel. "Combining Income and Wealth: An Analysis of Farm Family Well-Being." *Amer. J. Agr. Econ.* 55(1973):38–44.

Chipeta, C. "Family Farm Organization and Commercialization of Agriculture." Ph.D. thesis, Washington University, 1976.

Federal Task Force on Agriculture. *Canadian Agriculture in the Seventies*. Ottawa: Queens Printer, 1969.

Fitzpatrick, J. M. "Distribution of Incomes in Canadian Agriculture." Paper presented to the 35th Annual Meeting of the Canadian Agricultural Economics Society, Ottawa, 1965.

Freeman, W. G. "An Introduction to the Agriculture-Population Linkage Program." *Can. Farm Econ.* 2 (1976):9–16.

Gellner, J., and B. H. Davey. "Farmers' Income Tax Records as a Source of Farm Income Data Statistics." Mimeographed. Ottawa: Agriculture Canada, 1974.

Gunn, T. C. "Part-Time Farming in Nova Scotia." *Can. Farm Econ.* 13(1978):25–41.

Hansen, R. J., and R. Spitz. "Increasing Incomes of Farm Families through Dual Employment." *Agr. Finan. Rev.* 35(1974):59–64.

Huffman, W. E. "Interactions between Farm and Nonfarm Labor Markets." *Amer. J. Agr. Econ.* 59 (1977):938–46.

Jenkins, G. P. "Analysis of Rates of Return from Capital in Canada." Ph.D. thesis, University of Chicago, 1972.

Kenya Central Bureau of Statistics. "Non-Farm Activities in Rural Kenya Households." *Social Perspectives* 2(1977):1–12.

Kulshreshtha, S. N. "An Approach to Develop Comparisons of Farm and Non-Farm Incomes in Canada." *Can. J. Agr. Econ.* 14(1966):61–76.

———. "Measuring the Relative Income of Farm Labor, 1940–61." *Can. J. Agr. Econ.* 15(1967):28–43.

Larsen, D. W., and H. Y. Hu. "Factors Affecting the Supply of Off-Farm Labor among Small Farmers in Taiwan." *Amer. J. Agr. Econ.* 59(1977):549–53.

Larson, D. K. "Impact of Off-Farm Income on Farm Family Income Levels." *Agr. Finan. Rev.* 36 (1976):7–11.

McClutchy, D., and C. Campbell. "An Approach to Identifying and Locating the Low-Income Farmer." *Can. Farm Econ.* 10(1975):1–12.

Rust, R. S. "Farm Business Financing and Taxation Relationships." *Can. Farm Econ.* 9(1977):9–18.

Schuh, G. E. "Current Challenges for Agricultural Policy." *West J. Agr. Econ.* 3(1978):237–43.

Schultz, T. W. "The Increasing Economic Value of Human Time," *Amer. J. Agr. Econ.* 54(1972):843–50.

Shaw, R. P. "A Record Linkage System as a Means to Extensive Socio-Economic Farm Population Data." *Socio-Economic Planning Sci.* 5(1971):221–30.

———. *Canada's Farm Population.* Ottawa: Queens Printer, Canada Census Monograph, 1979a.

———. "Education, Multiple Jobholding and Agricultural Development." Mimeographed. Geneva: International Labor Organization, 1979b.

———. "Incomes, Adequacy of Income and Relative Poverty in Canada's Farm Sector." Mimeographed. Ottawa: Agriculture Canada, 1977.

———. "On Shifts in Parity, Poverty and Sources of Farm Family Income in North America." *Econ. Develop. and Cultur. Change* 27(1979c):645–53.

Soejono, I. "Growth and Distributional Changes of Paddy Farm Incomes in Central Java, 1968–74." Ph.D. thesis, Iowa State University, 1977.

Statistics Canada. *Family Expenditures in Canada, 1969, vols. I, II, III.* Ottawa, Cat. 62-535-7, 1973a.

———. *Housing: Dwelling Characteristics by Type of Dwelling.* Ottawa, Cat. 93-704, 1975.

———. *Incomes, Assets and Indebtedness of Families in Canada.* Ottawa, 1973b.

———. *Life Tables, Canada and Provinces, 1970–72.* Ottawa, 4-2302-591, 1974.

———. *National Income and Expenditures Accounts, 1926–74.* Ottawa, 3-1100-502, 1976.

———. *Net Farm Income.* Ottawa, 5-3104-504, 1973c.

Szenberg, A. "Present Trends in Non-Farm Income." *Zagadnienia Ekonimiki Rolnej* 4(1976):42–57.

Weisbrod, B. A., and W. L. Hansen. "An Income-Net Worth Approach to Measuring Economic Welfare." *Amer. Econ. Rev.* 58(1968):1315–30.

Area and Yield Response to Price Policy: A Case Study in Guatemala, C.A.

Carlos Pomareda and Otto Samayoa

The responsiveness of farmers to changes in the price of a particular product are dictated by many conditions, which include resource endowments—especially land and family labor—choice of crops and techniques, off-farm employment possibilities, relative product prices, and the presence of uncertainty in returns and the farmers' attitudes toward risk. In trying to measure the price responsiveness of farmers, alternative methods have been used. The advantages and disadvantages of such methods for estimating supply functions, i.e., linear programming (LP) models, production functions, and econometric analysis of time-series and cross-section data, have been widely discussed since the pioneering work of Nerlove and Bachman. More recently, Shumway and Chang highlighted the advantages of LP versus alternative methods. The limitations of LP models, however, related their capacity to reflect the actual situation because of misspecification of the farmers' goals, the stepped nature of the production possibilities, or resource constraints. The majority of cases have used fixed supply of inputs, hence implying the short run. If these problems are overcome, LP can be an effective tool for simulating the actual behavior of farmers.

Numerous studies of agriculture in developing countries have shown varied and contrasting evidence of the supply responsiveness of traditional farmers (see Askari and Cummings). Most of these studies, based either in positivistic analysis or in normative models, concentrate on measures of output elasticities, with limited discussion of the area and yield changes. The majority of econometric models use the adaptive expectations Nerlovian approach, in which only area planted is a function of expected prices. It is recognized that, under such specification, the analysis underestimates the actual responsiveness to price (Houck and Gallagher). A few of these studies, however, have explicitly included area and yield responsiveness to product prices (Tweeten and Quance, Herdt). However in programming models used to estimate supply responsiveness, no explicit reference is made to results which show the two components of output elasticity.

A regional linear programming model was implemented for the south Pacific region of Guatemala. The model incorporates the most important actual constraints and takes into account farmers attitudes as risk-averter individuals. Basic results for the model were comparable to the situation observed, as far as levels of resource use, areas planted, and production levels. A complete description of the model can be found in the work of Pomareda and Samayoa. The model builds on two types of substitution: (*a*) each crop can be produced in several ways, i.e., various points in the production function, and (*b*) crops compete for scarce resources. Therefore, any increase in price of a particular product will result in increases in production derived from increases in yield in area planted at the expense of other crops.

Economic Rationale and Model Overview

The basic model specifies that for the ith crop:

$$Q_i = f(Y_i, A_i), \tag{1}$$

$$Y_i = g(P_i/P, C, W, T_{is}), \tag{2}$$

$$A_i = h(P_i/P_j, C), \tag{3}$$

where, for the crop, Q_i is total production, Y_i is yield per unit of area, A_i is area planted, P_i is the expected price, P is an aggregate of expected prices for other products, W is a factor that takes into account weather and other elements that make yields stochastic, T_{is} is the technology s for production of crop i, and C is an aggregate of input prices.

For risk-averse farmers, the model can be formulated in linear programming form as

$$\text{Max} \sum_i P_i Q_i - \sum_i \sum_k \sum_s C_k b_{iks} - \Phi V^{1/2}, \tag{4}$$

$$\text{subject to, } b_{iks} \leq \mathbf{B}_k, \tag{5}$$

where, in addition to the terms already defined, C_k is the price of the kth resource; b_{iks} is the amount used of the kth resource by the ith crop; $\mathbf{B}_k$ is a vector of resource constraints; V is a variance-covariance matrix of gross returns, which accounts

Carlos Pomareda and Otto Samayoa are agricultural economists with the Center for Studies in Central American Integration and Development (ECID) of the General Secretariat of Central American Economic Integration (SIECA).

The views here expressed are those of the authors and they should not be ascribed to SIECA. The authors acknowledge comments by Jerry Carlson, Enrique Delgado, Roger Norton, James Seagraves, and two anonymous reviewers.

for the risk implicit in the uncertainty in yields and prices; and Φ is a subjective constant risk-aversion parameter, which reflects the attitudes of farmers towards risk.

The model incorporates two types of farms prevailing in the region, large commercial and small traditional. The first is dedicated to basic grains and to export crops, i.e., cotton, sugar cane, and coffee. The second group is dedicated to basic grains, i.e., maize, rice, and beans, sesame associated with maize, and beans associated with maize and cassava (yuca).

Techniques for production actually observed in the region were specified, implying that labor, machinery, and animal power are substitutes, and changes in their relative amounts imply movements along the same isoquant. Four possible combinations were chosen. The use of fertilizer, chemical inputs, and better cultural practices implies higher yields, hence shifts in the isoquants. Also, four possibilities of intensity of use in inputs were chosen. As a result, each crop could be produced in as many as sixteen possible ways on each type of farm. The choice of technique was made on the basis of the access to inputs; and the adoption of a particular technique by each type of farmer implies changes in yields because of differences in managerial capacity.

Requirements of land, labor, animal power, and machinery are specified on a monthly basis and their supply is assumed fixed. Requirements of fertilizers, chemicals, and other inputs are specified on an annual basis and their supply is assumed perfectly elastic. Credit is required for the purchase of hired labor, machinery, fertilizers, chemicals, and other inputs; and the supply of credit is assumed perfectly elastic at the given market interest rate.

In the labor market, small farmers depend only on family labor, but they can also work on commercial farms. The latter depend on permanent residents, and when these are exhausted, they can hire small farmers and landless peasants within the region and migrant workers from the neighboring regions, particularly from the Highlands.[1]

Accounting for risk measures has been recognized in linear programming models of the agricultural sector. The model incorporates risk measures and risk aversion parameters as suggested by Hazell. The constant risk-aversion coefficient, Φ, reflects the farmers attitudes toward risk, and larger absolute values reflect more conservative attitudes. The model was solved at alternative levels of Φ for both groups of producers. Values of $\Phi_1 = 0.5$ and $\Phi_2 = 1.5$ for large commercial and small traditional producers, respectively, provided cropping plans that most accurately reflected the actual situation. These values of Φ are consistent with studies of the attitudes of producers by Moscardi and de Janvry and Dillon and Scandizzo; Pomareda and Simmons; and Hazell, Norton, Parthasarathy, and Pomareda. The importance of risk in determining the characteristics of supply response is discussed and empirically illustrated in the work of Hazell, Norton, Parthasarathy, and Pomareda.

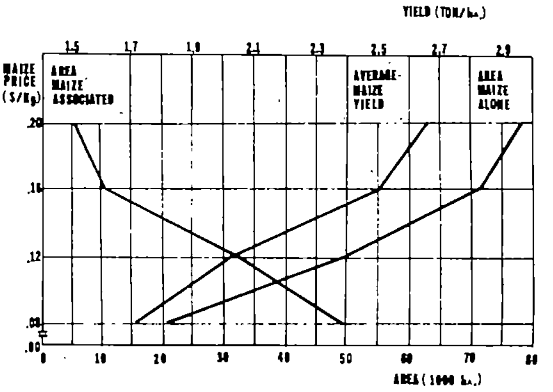


Figure 1. Maize area and yield response to prices in small farms

The Responsiveness to Price

At the given levels of resource use and risk parameters, the model reflected satisfactorily the behavior of farmers; areas planted, technology mix, crop yields, total production, resource use, and shadow prices fell close to the actually observed levels in the base period. The model was then used to measure the supply elasticity of maize and to evaluate the process of technique adoption and crop-to-crop substitution, in response to changes in maize price.[2] Prices of other crops, prices of inputs, and resource endowments were held at basic levels. Given the assumptions about the fixed supply of resources and the availability of technologies actually used by producers in the area, the situation analyzed reflects the short run.

Of particular interest was the nature of supply response in small farms. Table 1 shows the process of technique adoption by small farmers brought about by higher prices of maize. Higher prices motivate farmers to adopt more input-intensive higher-yielding techniques that are also riskier (see table 2) and farmers plant smaller areas of maize associated with other crops, which were initially chosen as a way to avoid risks. Incidentally, at prices higher than $0.12 per kilogram, the total area planted in maize (alone plus associated) remains constant, but there is substitution between maize associated with other crops, by maize alone, which

[1] Labor is particularly scarce in critical periods at planting, weeding, and harvesting during the crop season; yet there is significant unemployment during other periods of the year.

[2] In Central America, maize is the most important food crop. In Guatemala in 1970, maize provided 55% of the calories for the lower income, 85%, of the population; and maize used 734,700 hectares, representing 53% of the total area cultivated by annual and perennial crops excluding pastures (SIECA/FAO, 1974).

Table 1. Area, Production, and Yields, and the Process of Technique Adoption in Response to Maize Prices in Small Traditional Farms

Variables	Price of Maize ($/kg)[a] 0.08	0.12	0.16	0.20
Areas: (hectares)[b]				
*MAD*2	21,044	34,077	22,942	16,659
*MAD*3	0	15,834	48,302	60,868
*MJA*1	0	0	0	5,162
*MJA*2	40,527	25,052	11,445	0
*MJD*2	1,829	0	0	0
*MFA*1	6,629	7,726	0	0
Total maize[c]	70,029	82,689	82,689	82,689
Maize alone[d]	21,044	49,911	71,244	77,527
Maize associated[e]	48,985	32,778	11,445	5,162
Production (tons)				
maize	120,292	166,477	206,948	219,615
Yield (kg./ha.)				
maize	1,718	2,013	2,503	2,656

Note: Maximum supply of land equals 82,689 hectares.
[a] 1 Central American peso = 1 U.S. dollar.
[b] 1 hectare (ha.) = 2.45 acres.
[c] Sum of all techniques.
[d] Sum of techniques *MAD*2 and *MAD*3.
[e] Sum of techniques *MJA*1, *MJA*2, *MJD*2, and *MFA*1.

has a higher average yield. These facts are of particular interest in the measurement of direct and cross-price elasticities of supply, especially in developing an agriculture where many of the crops are grown associated, as a way to reduce risk.

Figure 1 illustrates the shape of the area and yield-response functions to price for small farms. Over the full price range simulated, the elasticities of supply measured at average price and quantity levels are +0.50, +1.336, and −1.89, for yield, area of maize alone, and area of maize associated, respectively. The resulting net output elasticity is +0.68. The elasticity of yield, not frequently measured in studies of supply response, is consistent with the results of Houck and Gallagher, who reported corn yield elasticities between 0.24 and 0.76, estimated with alternative econometric models. The region's aggregate maize output elasticity measured over the same range and at the average price and quantities, is 0.81. The large commercial farmers output elasticity is 0.96. The latter is only an area response, because yields remained constant at already high levels for the larger farmers.

The overall effect of price changes at the regional level is shown in table 3. Over the range simulated, expanded production of maize in small farms is at the expense of the production of sesame and beans. It must be recalled that sesame and beans are pro-

Table 2. Resource Use, Risk, and Yields of the Techniques Used for Maize Production in Small Farms (per hectare)

Technique	Labor *m-d*	Oxen *o-d*	Machinery *t-h*	Type Of Seed[a]	Chemicals $	Fertilizers *N* kg.	*P* kg.	Variability of Returns[b] $	Yields Maize kg.	Other kg.
*MAD*2	70.6	17.2	4.0	L	1.8	0	0	368.56	2,600	0
*MAD*3	49.1	4.3	8.7	H	7.2	56	56	583.12	3,250	0
*MJA*1	112.3	0	0	L	6.5	0	0	340.36	1,300	520[c]
*MJA*2	110.6	0	0	H	30.3	26	26	408.88	1,625	780[c]
*MJD*2	125.5	9.2	4.0	H	5.3	26	26	408.88	1,560	780[c]
*MFA*1	130.5	0	0	L	9.7	0	0	443.16	1,300	780[d]

Note: *m-d* is man-day; *o-d* is oxen-day; *t-h* is tractor-hour.
[a] *L* is local, *H* is hybrid.
[b] Calculated as the sum of absolute deviations of returns from the regression line over a ten-year period, in order to eliminate the time effect on yields and prices. The measure of variability is an approximation of the standard deviation instead of the variance (see Hazell, and Pomareda and Simmons).
[c] Sesame.
[d] Beans.

Table 3. Regional Production of Maize and Other Crops, in Response to Maize Prices (tons)

Crop	Price of Maize ($/kg.) 0.08	0.12	0.16	0.20	Effect
Small farms					
Maize[a]	120,292	166,477	206,948	219,615	(+)
Sesame[b]	33,038	19,540	8,927	2,683	(−)
Beans[b]	5,171	6,026	0	0	(−)
Yuca[c]	9,618	9,618	36,434	13,210	(−)
Commercial farms					
Maize[d]	89,567	185,490	215,533	215,160	(+)
Rice	265,222	130,734	36,434	13,210	(−)
Cotton	350,418	377,298	409,084	417,965	(+)
Sugar Cane	4,978,688	4,338,503	4,488,403	4,513,924	(?)
Coffee	150,575	202,890	195,989	197,185	(?)

[a] Produced alone and associated with sesame and beans.
[b] Produced only associated with maize.
[c] Cassava.
[d] Produced alone.

duced only in association with maize; but when the price of maize increases, these areas diminish and maize is grown alone, using more input-intensive techniques. In large farms, expanded maize production takes place at the expense of upland rice. Interestingly, the increase in maize production, using techniques more intensive in machinery and other purchased inputs, frees labor in small farms, and off-farm employment increases. Hence cotton, the most labor-intensive crop, grown only in large commercial farms, responds positively to the increases in the price of maize. Sugar cane and coffee do not show any definite positive or negative relationship. Coffee is grown on a different type of land and it is a permanent crop, and sugar cane is a five-year crop.

This paper has presented results of a linear programming model to determine the yield and area components of output elasticity. The approach was found to be of particular relevance in developing agriculture, where land and family labor are extremely scarce; hence, any increase in food production would have to take place through increases in yields, intensifying the use of inputs, such as fertilizers, improved seeds, and technology.

[*Received September 1978; revision accepted March 1979.*]

References

Askari, H., and J. T. Cummings. "Estimating Agricultural Supply Response with the Nerlove Model: A Survey." *Int. Econ. Rev.* 18(1977):257–92.

Dillon, J. L., and P. L. Scandizzo. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach." *Amer. J. Agr. Econ.* 60(1978):425–35.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1971):53–62.

Hazell, P. B. R., R. D. Norton, M. Parthasarathy, and C. Pomareda. "The Significance of Risk in Agricultural Planning." World Bank Staff Work. Pap. No. 307, Nov. 1978.

Herdt, R. W. "A Disaggregate Approach to Aggregate Supply." *Amer. J. Agr. Econ.* 52(1970):512–20.

Houck, J. P., and P. W. Gallagher. "The Price Responsiveness of U.S. Corn Yields." *Amer. J. Agr. Econ.* 58(1976):731–34.

Kutcher, G. P., and P. L. Scandizzo. "The Northeast Brazil Modeling Effort: A Progress Report." Mimeographed. Washington, D.C.: Development Research Center, World Bank, 1976.

Moscardi, E., and A. de Janvry. "Attitudes Towards Risk among Peasants: An Econometric Approach." *Amer. J. Agr. Econ.* 59(1977):710–16.

Nerlove, M., and K. Bachman. "The Analysis of Changes in Agricultural Supply: Problems and Approaches." *J. Farm Econ.* 42(1960):531–54.

Pomareda, C., and R. L. Simmons. "A Programming Model with Risk to Evaluate Mexican Rural Wage Policies." *Operational Res. Quart.* 27(1977):997–1011.

Pomareda, C., and O. Samayoa. "El Modelo del Sector Agrícola de la Región IV de Guatemala." Guatemala: ECID SIECA Informe No. 3, Mar. 1978.

SIECA/FAO. *Perspectivas por el Desarrollo y la Integración de la Agricultura en Centroamérica,* vol. 2. Guatemala: SIECA, May 1974.

Shumway, R., and A. A. Chang. "Linear Programming vs. Positively Estimated Supply Functions: An Empirical and Methodological Critique." *Amer. J. Agr. Econ.* 59(1977):344–57.

Tweeten, L. G., and C. L. Quance. "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches." *Amer. J. Agr. Econ.* 51(1969):342–52.

The Structure and Changes of Technology in Prewar Japanese Agriculture

Le Thanh Nghiep

The nature of technical progress of the Japanese agricultural sector has been discussed intensively; yet, the literature still does not give a satisfactory explanation consistent with important aspects of the experience. The purpose of this note is to develop an interpretation that is capable of explaining the technical progress of the Japanese agricultural sector and is consistent with present knowledge about Japanese economic history.

Regarding technical changes in the Japanese agricultural sector in the period 1900–40, the migration of labor from farming and the decrease in the prices of commercial fertilizers and other nonagricultural inputs are considered critical. The sustained high growth rate of labor productivity of the nonagricultural sector induced a continuous stream of off-farm migratory labor which was not totally offset by the growth in the labor force due to the natural increase of rural population. In addition, there was a tendency for the price of commercial fertilizers to decline as a result of the increase in fertilizer imports and of cost improvements in the domestic fertilizer industry. These changes in factor endowments and prices caused an intersectoral reallocation of resources resulting from factor substitution and technical changes.

It is hypothesized that the agricultural sector of Japan during the concerned period was locked into extremely narrow regions of factor substitution, and large parts of changes in the input levels of factors were due to biased technical changes. It also is hypothesized that biased technical changes were more or less induced by the changes in the relative prices of factors in directions that eased the restrictions imposed by resource endowments.[1] In what follows, an analytical framework will be set, based on which statistics then will be computed from Japan's 1903–38 data to test the above-stated hypotheses.

Le Thanh Nghiep is an agricultural economist at the International Development Center of Japan, Tokyo.

This paper is the result of research for the Rural Development Project undertaken at the International Development Center of Japan (IDCJ). The author is greatly indebted to Kazushi Ohkawa, Yujiro Hayami, and two anonymous reviewers for helpful comments.

[1] Hayami and Ruttan introduced this notion in agricultural analysis. However, the notion of technical progress, induced by relative prices of production factors, had been disputed previously by Hicks, Fellner, Ahmad, Kennedy, among others (see Ferguson).

Analytical Framework and Method of Estimation

The shapes of the isoquants at a given point of time and the over-time shifts of these curves present the essential aspects of the technology of an economy. The shapes of the isoquants, in turn, are characterized by the partial elasticities of substitution between factors. It is on this basis that the analytical framework to be employed was derived. Two categories of partial elasticities of substitution will be distinguished and estimated. One corresponds to the substitution possibilities for a given technology. The other one includes over-time changes of technology. In figure 1, a change in the input combination from A to B, corresponding to relative prices P_1 and P_2, can be analyzed in two ways. First, the

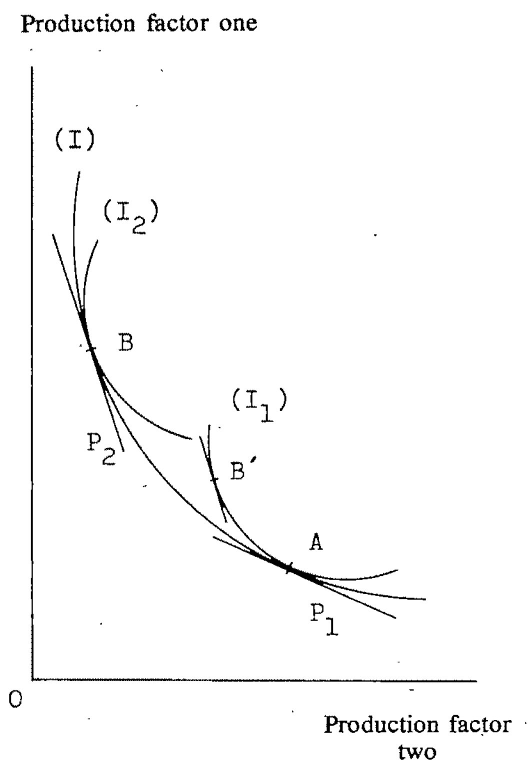


Figure 1. Resource allocation under the prevailing technology and through technical changes

change can be fragmented into a substitution effect presented by the movement from A to B' along isoquant I_1 and a biased effect of technical change from B' to B. By eliminating the effect of the technical change, one can obtain the partial elasticities of substitution for a given technology. Second, an isoquant like I can be interpreted as enveloping curves I_1 and I_2 from below and, thus, yielding the second concept of substitution elasticity.

Method of Estimation

A modified translog cost function approach was used in the analysis. The approach is a slight modification of that first applied by Binswanger. The modification is presented in some detail by Nghiep 1977. Corresponding to the two types of isoquant illustrated in figure 1, there exist the following two cost functions:

$$(1) \qquad C = F_1(P_1, P_2, \ldots, P_n, Y, T_e),$$

$$(2) \qquad C = F_2(P_1, P_2, \ldots, P_n, Y),$$

in which C is the minimizing cost; P_is, prices of n production factors; Y, output level; and T_e, a technical index.

The presence of the technical index in function (1) permits estimation of the partial elasticities of substitution of the first type and specification of the nature of technical bias. Equation (2) corresponds to the meta-production function (Hayami and Ruttan). As technical changes generally consist of price-induced and nonprice components, there should be three different effects associated with the prices and technical index in equations (1) and (2): a price-induced technical bias, a nonprice-induced technical bias, and a substitution effect. In equation (1) the price variables identify the substitution effect, and the technical index captures both price-induced and nonprice-induced technical biases. On the other hand, the price variables in equation (2) are expected to remove the substitution effect and price-induced technical biases.

A direct application of Shephard's lemma, equalizing the first derivative of the cost function with respect to the price of a factor to its input level, leads to a group of regression equations from which demand elasticities, partial elasticities of substitution, and their standard deviations can be calculated (Binswanger, Berndt and Wood, Halvorson). However, there is little assurance that this equilibrium condition holds in the short run. In the present paper, Shephard's lemma is assumed to hold at the long-run equilibrium level of input to which its observed level is related by a distributed lag scheme (Nerlove). As a result, the estimation is made rather complicated and the variances of the estimates of the required elasticities cannot be directly calculated.

The cost function is defined as

$$(3) \ \ln C = \nu_o + \nu_y \ln Y + \nu_t \ln T + \sum_{i=1}^{n} \nu_i \ln P_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln P_i \ln P_j + \sum_{i=1}^{n} \gamma_{iy} \ln P_i \ln Y + \sum_{i=1}^{n} \gamma_{it} \ln P_i \ln T + \gamma_{yt} \ln Y \ln T,$$

where $\gamma_{ij} = \gamma_{ji}$ (the symmetry constraint), and $\sum_i \nu_i = 1$, $\sum_i \gamma_{ij} = 0$, $\sum_i \gamma_{iy} = 0$, and $\sum_i \gamma_{it} = 0$ (linear homogeneity in input prices). The time variable T is used as a proxy for the technical index.

By assuming that the corresponding production function is homothetic, so that $\gamma_{iy} = 0$, and using Shephard's lemma, the following equations are obtained:

$$(4) \ \frac{\partial \ln C}{\partial \ln P_i} = \frac{\partial C}{\partial P_i}\frac{P_i}{C} = X^*_i \frac{P_i}{C} = S^*_i = \nu_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \gamma_{it} \ln T,$$

for $i = 1, 2, \ldots, n$ and where X^*_i and S^*_i indicate the desired levels of input and cost share of factor i. The S^*_i's are defined by

$$(5) \qquad (S_{it} - S_{it-1}) = \alpha_i (S^*_{it} - S_{it-1}).$$

In the equations, S_{it} stands for the real share of factor i at time point t. Because the real or desired shares of all factors sum up to 1, equation (5) implies[2]

$$(6) \qquad \alpha_i = \alpha.$$

The following system of regression equations is thus obtained:

$$(7) \ S_{it} = \alpha\nu_i + \sum_j \alpha\gamma_{ij} \ln P_j + \alpha\gamma_{it} \ln T + (1 - \alpha) S_{it-1},$$

with constraints,

---

[2] Summing each term in (5) over n variables,

$$0 = \sum_{i=1}^{n} \alpha_i S^*_{it} - \sum_{i=1}^{n} \alpha_i S_{it-1}.$$

Since $\quad S^*_{nt} = 1 - \sum_{i=1}^{n-1} S^*_{it}$ and $S_{nt-1} = 1 - \sum_{i=1}^{n-1} S_{it-1},$

$$0 = \sum_{i=1}^{n-1} (\alpha_i - \alpha_n)(S^*_{it} - S_{it-1}).$$

This identity would always hold if

$$(\alpha_i - \alpha_n) = 0, \text{ or } \alpha_i = \alpha_n = \alpha.$$

$$(8)\ \gamma_{ij} = \gamma_{ji},\quad \sum_i \gamma_{ij} = 0,\quad \sum_i \nu_i = 1,\quad \sum_i \gamma_{it} = 0,$$

where $i, j = 1, 2, \ldots, 4$ are the indices for the factors of production and $t = 1, \ldots, 35$ denotes the time periods. The partial elasticities of substitution are computed as

$$(9)\qquad \sigma_{ij} = \frac{\gamma_{ij}}{S^*_i S^*_j} + 1, \text{ and}$$

$$(10)\qquad \sigma_{ii} = \frac{1}{S^*_i}(\gamma_{ii} + S^{*2}_i - S^*_i).$$

Technical biases will be factor i using, neutral, or saving, according to the sign—plus, zero, or minus—of the coefficient γ_{it}. The restricted generalized least squares method (GLS) of regression (Theil) was applied to compute $\alpha\nu_i$'s, $\alpha\gamma_{ij}$'s, $\alpha\gamma_{it}$'s, and α, and the associated var-covariance matrix. Then the elasticities of substitution σ_{ij}'s and their confidence limits were calculated from these estimates (Nghiep 1977).

Data

The estimation of the differential equations derived from the cost functions presented in the last section requires observations of prices and cost shares of factors. To obtain factor shares, in addition to prices, the quantities of inputs also are needed. The data about factor shares and prices used in the present paper are shown in table 1.

Production factors are classified into five categories: labor, land, fertilizer, machinery, and others. The other factors include nonfertilizer current capital and nonmachinery-fixed capital. The data for prices and quantities, except that for labor quantity, are based on long-term economic statistics (Ohkawa, Shinohara, Umemura). The figures used for labor input are from the revised series of Yamada and Hayami, constructed from Umemura's revised series of total gainful workers employed in agriculture and forestry. Rent is taken as the price of land, and the machinery expenditure is represented by the total depreciated value of power machinery, tools, and implements. Other fixed capital expenditures included in the category of other factors are represented by their depreciated values. The wage rate of yearly contract workers is used as the price of labor.

The price indices indicate that wage was the most rapidly rising price in the period 1903–38. After wage, prices of land, machinery, and "other" rose most dramatically. Fertilizer price increased least during the period. On the basis of induced technical changes, it is expected that technical biases would be of the inverse order. That is, if γ_{LAB}, γ_{LAN}, γ_{FER}, γ_{MAC}, and γ_{OTH} stand for the technical coefficients of labor, land, fertilizer, machinery, and other factor, respectively, the inequalities $\gamma_{LAB} < \gamma_{LAN} < \gamma_{OTH} < \gamma_{MAC} < \gamma_{FER}$ must hold.

Estimation Results

Because the items included under the "other" category are rather heterogenous from nonfertilizer current inputs to nonmachinery fixed capital, characteristics of the elasticities of substitution related to this factor will not be discussed. The estimated partial elasticities of substitution and technical biases of labor, land, fertilizer, and machinery will be examined.

Estimates are presented in table 2. The partial elasticities of substitution are shown in table 3. The GLS coefficients for the four share equations, including the time variable, are rather high: .79 for labor, .96 for land, .80 for fertilizer, and .93 for machinery. The coefficients for the equations not including the time variable are .58, .96, .40, and .96 for labor, land, fertilizer, and machinery, respectively.

Technical Biases

The figures in table 2 show, on an annual basis over the period 1903–38, a decrease of .48% in labor share, an increase of 1.3% in fertilizer share, an increase of .25% in machinery share, and an increase of .24% in the share of factors included in the other category. These technical biases correspond

Table 1. Factor Shares and Indices of Factor Prices

	Labor		Land		Fertilizer		Machinery		Other	
Year	Price	Share	Price	Share	Price	Share	Price	Share	Price	Share
		(%)		(%)		(%)		(%)		(%)
1905	100	48.5	100	28.9	100	4.0	100	4.1	100	14.5
1910	117	48.7	114	29.5	84	5.3	97	3.8	98	12.7
1915	133	46.0	120	28.7	93	6.6	129	5.4	103	13.3
1920	329	49.2	261	27.5	158	6.6	207	3.7	228	13.0
1925	376	51.7	238	25.3	127	6.7	141	3.4	209	12.9
1930	279	52.8	157	23.1	83	6.9	132	4.3	153	12.9
1935	240	45.0	177	27.4	82	8.2	149	4.9	155	14.5

Note: All figures are five-year averages centering on the years shown.

Table 2. Restricted Coefficients of Translog Cost Functions

	Price of Labor	Price of Land	Price of Fertilizer	Machinery Price	Price of Other	Year	Lagged Variable
Time variable included:							
Share of labor	.1746	−.1060	−.0194	−.0135	−.0356	−.0355	.1544
	(.0168)[a]	(.0088)	(.0068)	(.0024)	(.0137)[b]	(.0052)	(.0366)
Share of land		.1937	−.0144	−.0180	−.0552	.0001	.1544
		(.0109)	(.0060)	(.0023)	(.0129)	(.0026)	(.0366)
Share of fertility			.0295	−.0108	.0152	.0230	.1544
			(.0063)	(.0023)	(.0092)	(.0025)	(.0366)
Share of machinery				.0411	−.0096	.0032	.1544
				(.0022)	(.0036)	(.0007)	(.0366)
Share of other					.0852	.0092	.1544
					(.0196)[b]	(.0039)	(.0366)
Time variable not included:							
Share of labor	.0995	−.0991	.0254	−.0054	−.0204		.2195
	(.0115)	(.0074)	(.0067)	(.0022)	(.0103)		(.0383)
Share of land		.1874	−.0119	−.0185	−.0577		.2195
		(.0107)	(.0054)	(.0024)	(.0131)		(.0383)
Share of fertilizer			−.0006	−.0128	−.0001		.2195
			(.0056)	(.0021)	(.0103)		(.0383)
Share of machinery				.0382	−.0013		.2195
				(.0019)	(.0040)		(.0383)
Share of other					.0911		.2195
					(.0218)		(.0383)

[a] The figures in parentheses are standard errors.
[b] The standard errors in the column "price of other" and that of the time coefficient in the line "share of other" were computed from the var-covariance matrix of other coefficients and the imposed restrictions: $\sum_i \gamma_{ij} = 0$ and $\sum_i \gamma_{it} = 0$.

to expected changes in factor prices and, thus, support the hypothesis that technical changes in the period resulted from private and public efforts to ease resource constraints.

Partial Elasticities

All partial elasticities of substitution, except those of the fertilizer-machinery pair, corresponding to

Table 3. Estimates of Partial Elasticities of Substitution

	Land	Fertilizer	Machinery	Other
Time variable included:				
Labor	.061	.230	.215	.357
	(−.099, .222)	(−.336, .783)	(−.042, .483)	(−.158, .865)
Land		−.029	−.859	−.787
		(−.947, .845)	(−1.424, −.339)	(−1.711, .084)
Fertilizer			−3.945	3.176
			(−5.759, −1.840)	(.497, 5.910)
Machinery				−1.023
				(−2.546, .546)
Time variable not included:				
Labor	.043	2.080	.656	.602
	(−.115, .190)	(1.504, 2.647)	(.393, .943)	(.092, 1.116)
Land		.088	−1.083	−1.006
		(−.797, .938)	(−1.781, −.475)	(−1.969, −.066)
Fertilizer			−5.344	.990
			(−7.791, −3.208)	(−2.239, 4.238)
Machinery				.709
				(−1.192, 2.560)

Note: In parentheses are upper and lower limits of the 5% significance level.

the cost function including the time variable, have absolute values of less than 1. Moreover, at the 5% significance level most of these estimates appear not significantly nonzero. These figures, thus, support the hypothesis that prewar Japan's agricultural sector was characterized by an inflexible structure of technology.

Machinery appears to have been a substitute for labor and a complement to land. While the labor-machinery technical relationship is apparently plausible in every respect, the estimate for the land-machinery pair supports Hayami-Ruttan's view in favor of its complementarity and differs from Binswanger's result for the case of the United States. The negative elasticity of substitution computed for fertilizer-machinery pair indicates that these two factors are complements for each other.

The partial elasticities of substitution corresponding to the cost function not including the time variable incorporate both the substitution effect and the price-induced technical bias. Most relevant estimates are of similar signs and have larger absolute values when compared with those that include the time variable. The large absolute values for labor-fertilizer and labor-machinery pairs are especially noteworthy. They indicate that price-induced technical changes in the period 1903–38 did result in an enlargement of the substitutional regions, especially of those between the most scarce resource (labor) and the newly invented inputs that became cheap (fertilizer and machinery).

The positive elasticity of substitution for the labor-fertilizer pair requires careful consideration. Although fertilizer is commonly believed to be a complement to labor, the estimate appears quite consistent with the author's expectation. Self-supplied fertilizers which required farm labor for their production were extensively used in Japan until the 1900s. Consequently, as wages rose and labor became scarce, commercial fertilizers were substituted for self-supplied fertilizers, the price of which was increased by rising farm labor wages (Nghiep and Sakiura, Nghiep 1975). It is useful to notice that Hayami and Ruttan, although emphasizing the possible complementary relationship between labor and fertilizer, did find a similar result in their quantitative analysis of Japanese agriculture for the same period.

The direct price elasticities of demand, corresponding to the cost function that includes the time variables, are −.089 for labor, .114 for land, −.372 for fertilizer, .202 for machinery, and −.116 for the other factor. Because the elasticities for land and machinery are positive, it should be understood that the cost function is not well behaved and that the resulting elasticities of substitution must be viewed with caution. However, there are reasons to support these results. First, because the agricultural sector itself is treated as the production unit, the cost function is not necessarily well behaved. Second, farmers conceivably could utilize their labor force to develop new land and to produce farm implements in slack seasons when the prices of these items rose.

Substitution Effect and Technical Biases

From the results associated with equations (1) and (2), if for the cost share of factor i a_i, b_i, and c_i stand for the substitution effect, the price-induced technical bias, and the nonprice-induced technical bias, respectively, the following relationship holds:

$$a_i = \sum_j \gamma_{ij} d\ln P_j, \tag{11}$$

$$b_i + c_i = \gamma_{it} d\ln T, \text{ and} \tag{12}$$

$$a_i + b_i = \sum_j \gamma'_{ij} d\ln P_j, \tag{13}$$

where γ indicates coefficients of the cost function including the time variable, and γ' indicates coefficients of the cost function without the time variable.

Using equations (11) to (13) effects of substitution, price-induced technical changes, and nonprice-induced technical changes can be computed. In the above equations, the lagged variable has been omitted for simplification. To determine the long-run effects of these variables, two steps were required. First, separate short-run effects of price and time, and the lagged variable contribution were calculated. The sum of separate effects of the prices and time corresponds to the total short-run effect of these variables, while the sum of this total short-run effect and the contribution of the lagged variable can be regarded as their total long-run effect. The separate short-run effects of the prices and time were then weighted by the ratio of these two sums to calculate these variables' separate long-run effects.

The results of the computation of different effects on factor shares in the period 1903–38 are presented in table 4. The price-induced technical biases are especially prominent in the cost shares of labor and fertilizer and negligible in the cost shares of land and machinery. The signs and the absolute values of these biases support the hypothesis on price-induced technical changes. Effects of nonprice-induced technical changes are large in the labor, fertilizer, and machinery shares.

Labor-Saving versus Labor-Using

The common view is that Japanese agriculture has been characterized by a labor surplus well into the first decades of the twentieth century.[3] This belief served as the rationale for a labor-using bias of agricultural technology in the prewar period

[3] The date of the turning point is still disputed among supporters of the turning-point theory. For example, Ohkawa and Rosovsky, Ohkawa, and Minami have chosen somewhere around 1955, while Fei and Ranis suggested some year around 1917.

Table 4. Substitution Effects and Technical Biases in Factor Shares (1903–38)

	Predicted Changes in Factor Shares				Actual Changes in Factor Shares
		Technical Biases			
	Substitution Effects	Price-Induced	Nonprice-Induced	Total	
			(%)		
Labor	8.9	−7.8	−6.0	−4.9	−4.1
	(−217)	(190)	(146)	(119)	(100)
Land	−2.1	−0.1	0.1	−2.1	−2.3
	(91)	(4)	(−4)	(91)	(100)
Fertilizer	−3.4	5.6	3.8	6.0	6.0
	(−57)	(93)	(64)	(100)	(100)
Machinery	0.2	0.4	0.8	1.4	1.2
	(17)	(33)	(67)	(117)	(100)

Note: Inside the parentheses are percentages with actual changes in factor shares set equal to 100.

(Sawada and Shintani). Even among neoclassical economists there are some who—through comparison of resource endowments between Japan and such land-abundant countries like the United States, Canada, and Australia—conclude that technical changes in Japanese agriculture essentially were attempts to compensate for limited land (Hayami and Ruttan).

This paper hypothesizes and provides empirical evidence that technical changes in prewar Japanese agriculture were labor-saving. The hypothesis is based on an analysis of the dynamic aspects of Japanese resource endowments in the period studied. A static comparison between Japan's resource endowments and those of land-abundant countries might result in the conclusion that the technical structure of Japanese agriculture was relatively land-saving and/or labor-using. However, a dynamic comparison with focus on changes over time in factor prices should bring to light the fact that Japan's agricultural wage was increasing and, in this way, verify the labor-saving hypothesis.

Biochemical Technology and Mechanical Technology

The main conclusions related to fertilizer and machinery can be summarized by the following: (*a*) fertilizer was a substitute for labor in the long-run, (*b*) machinery was a substitute for labor and a complement to the land, (*c*) machinery and fertilizer were complements for each other.

The first point may be a result of the particular circumstances prevailing in prewar Japan. This outcome is a characteristic of an economy in which self-supplied fertilizer had been intensively employed in agricultural production before labor—the major input in producing self-supplied fertilizer—became scarce as the development process progressed.

The conclusions related to machinery-labor and machinery-land relationships are somewhat more general. The higher the wages compared to machinery prices, the more speedy the diffusion rate is a relationship that can be expected. One might also expect to find the same relationship between high machinery-labor ratio and large farm-size.

The terms biochemical technology and mechanical technology are often used as if they were technically exclusive of each other. The results in this paper do not support this clearcut division. The negative elasticity of substitution between these two factors is quite consistent with the fact that these two categories of technology exist side by side in most parts of the world.

[*Received August 1977; revision accepted March 1979.*]

References

Berndt, E. R., and D. O. Wood. "Technology and the Derived Demand for Energy." *Rev. Econ. and Statist.* 57(1975):259–68.

Binswanger, H. P. "The Measurement of Technical Change Biases with Many Factors of Production." *Amer. Econ. Rev.* 64(1974):964–76.

Fei, J. C. H., and G. Ranis. *Development of the Labor Surplus Economy: Theory and Policy.* Homewood, Ill.: Richard D. Irwin, 1964.

Ferguson, C. E. *The Neoclassical Theory of Production and Distribution.* London: Cambridge University Press, 1969.

Halvorson, R. "Energy Substitution in U.S. Manufacturing." *Rev. Econ. and Statist.* 59(1977):381–88.

Hayami, Y., and V. W. Ruttan. *Agricultural Development: An International Perspective.* Baltimore, Md.: Johns Hopkins University Press, 1971.

Nerlove, M. *Estimation and Identification of Cobb-Douglas Production Function.* Chicago: Rand-McNally & Co., 1965.

Nghiep, L. T., and S. Sakiura. "Aggregation of Self-Supplied and Commercial Fertilizer Inputs: Some Implications to the Japanese Agricultural Stagnation in the 1920's." *J. Faculty Agr.* 58(1975):13–26, Hokkaido University.

Nghiep, L. T. "The Agricultural Stagnation in Prewar Japan: Its Causes and Implications to Economic Development Strategy." Ph.D. thesis, Hokkaido University, 1975.

———. *The Structure and Changes of Technology in Prewar Japanese Agriculture. International Development Center of Japan Work.* Pap. Ser. No. A-03, Tokyo, 1977.

Minami, R. *Transition from the Labor Surplus to the Labor Shortage Economy: The Turning Point in the Japanese Economy.* Tokyo: Kinokuniya Bookstore Co., 1973.

Ohkawa, K. *Differential Structure and Agriculture: Essays on Dualistic Growth.* Tokyo: Kinokuniya Bookstore Co., 1972.

Ohkawa, K., and H. Rosovsky. "A Century of Japanese Economic Growth." *The State and Economic Enterprise in Modern Japan,* ed. W. Lockwood. Princeton, N.J.: Princeton University Press, 1965.

Ohkawa, K., M. Shinohara, and M. Umemura, eds. *Estimates of Long-Term Economic Statistics of Japan since 1868,* vol. 9. Tokyo: Toyokeizaishinposha, 1966.

Sawada, S. "Effects of Technological Change in Japanese Agriculture." *Agriculture and Economic Growth: Japan's Experience.,* ed. K. Ohkawa, B. F. Johnston, and H. Kaneda. Tokyo: University of Tokyo Press, 1969.

Shintani, M. "Senzen Nihon Nogyo ni Okeru Gijutsuhenka to Seisan no Teitai (Technological Change and Stagnation of Production in Prewar Japanese Agriculture)." *J. Rural Econ.* 44(1972):11–19.

Theil, H. *Principles of Econometrics.* New York: John Wiley & Sons, 1971.

Yamada, S., and Y. Hayami, Revisions of the Yamada-Hayami paper "Growth Rates of Japanese Agriculture, 1800–1960." Report read at the Hawaii Conference on Agricultural Growth in Japan, Korea, Taiwan, and the Philippines, 1972.

Gross and Net Productivity: A Problem of Aggregation

Folke Dovring

Comprehensive productivity measures are sometimes regarded as superior to the more special ones such as labor productivity. In the words of Fabricant, "The best measure is one that compares output with the combined use of all resources" (p. 6). Rather than selecting one measure as "best" for all purposes, we should aim at understanding what the various measures mean and what analytical purposes they may serve.

The economic meaning of productivity measurement is a complex problem and will not be discussed here. Nor is it intended to repeat here the whole debate about index-number problems in productivity measurement. The focus is instead on a problem which has received relatively little attention; namely, how index numbers of productivity may be affected by the level of aggregation: a whole economy, major industry groups, individual industries, individual firms, or individual enterprises.

For this discussion, we will define gross and net productivity: gross productivity is the ratio of output over all inputs; net productivity is the ratio of value added over internal factors of production (land, labor, and capital internal to the industry or firm). The two concepts coincide when a whole national economy is analyzed. The two concepts generally differ more, the more disaggregated the analysis.

Net productivity has prevailed in most analyses to date. Gross productivity has begun to attract more attention in recent years (Christensen, Howe and Handy). The analytical purpose which gross productivity answers better than net productivity is that of assigning credit for productivity gains among the several factors which jointly generate these gains (Griliches, Pasinetti, Hulten).

A major problem with gross productivity is the fact that the apparent rate of productivity change is to some degree dependent on the level of aggregation chosen for analysis. The more disaggregated the treatment, the slower becomes the apparent rate of productivity change. This has been observed by Ruttan (1954, pp. 24–28; 1957, pp. 1570–74), Horring (pp. 46 ff.), and Dovring (p. 64). These previous observations will be restated in simple notation before an attempt is made to reconcile the results of gross and net productivity measurements.

For some schematic examples, let us first think of an industry (Industry 1) which for simplicity is treated as a closed system (no intermediate products are considered) and which may be disaggregated into two subindustries (Industry 1a and Industry 1b) which together comprise all the activity of Industry 1. Then, let gross productivity over some arbitrary time span increase by 10%. For Industry 1, we obtain

(1) $$110\ O_1/100\ I_1 = 110.$$

Suppose, further, that Industry 1a has half the outputs and inputs of Industry 1, maintaining the fictitious assumption of a closed system. For industry 1a the equation reads

(2) $$55\ O_{1a}/50\ I_{1a} = 110.$$

Industry 1b, which represents a later stage of production, absorbs the entire output of Industry 1a as input, along with its own internal factors of production, and turns out as its output the same final goods as Industry 1. We then obtain

(3) $$55\,O_{1a} + 55\,O_{1b}/55\,O_{1a} + 50\,I_{1b} = 110/105 = 104.76.$$

It now becomes obvious that rates of change in gross productivity are not comparable between units of analysis which represent different levels of aggregation (1b versus 1), or which absorb external inputs in their factor mixes in different proportion (1b versus 1a).

By contrast, net productivity changes are comparable irrespective of the level of aggregation. Netting out the factors absorbed from Industry 1a, we obtain for Industry 1b,

(4) $$55\ O_{1b}/50\ I_{1b} = 110.$$

How far gross productivity indexes differ from net indexes, and from each other, depends on several things, among which are the level of aggregation and the rate of productivity change. Level of aggregation may be represented by the ratio of value added to total output, or value-added ratio (*VAR*). The smaller this ratio, the lower the level of aggregation. The ratio is 100 at the highest level of aggregation; that is, the entire national economy, where all intermediate products are netted out and there are no "external" factors of production. The *VAR* is lower, the larger the "throughput" of external factors and can be quite low on highly specialized enterprises such as chicken farms and petroleum refineries. If Industry 1b had only 10% instead of 50% of value added in its gross output,

Folke Dovring is a professor of land economics at the University of Illinois-Urbana.

then its gross productivity index would be only 100.92.

Rate of change also affects the difference between gross and net productivity. If the index for Industry 1 were 200 instead of 110, then with 50% value added, Industry 1b would have an index of 133.33; with 10% value added, it would come to 105.26. Note that these cannot be aggregated even by exponential reckoning: 1.333 is less than the square root of 2, and 1.053 is less than the tenth root of 2. This will cause some minor difficulty with time series data, when the value-added ratio varies over time.

Different types of indices may not be directly comparable between themselves, yet they reflect in different ways the same reality. Work on aggregated-labor productivity in American agriculture (Dovring) showed that a long-run productivity trend from the early 1920s to the early 1960s reflected an acceleration factor of 3½% (of the rate of productivity change) per year, and that the same acceleration factor can be traced also in the otherwise widely differing indexes of both gross and net productivity.

This leads to the question how the differing rates of change in gross and net indexes may be reconciled. It appears that gross productivity indexes can be reduced to a comparable scale by translating them into net productivity indexes which are comparable in the sense that they can be aggregated into larger sectors, and into the whole economy, without difficulty. Provided the *VAR* is known, we can start from equations (3) and (4) above, where gross productivity (*GI*) was changed into net (*NI*) by removing the external factors from both sides of the expression. Consequently, external inputs can be computed as the difference between the gross index and the gross index multiplied by VAR, and the internal inputs as difference between all inputs and the external ones. We then write

$$\text{(5a)} \qquad \frac{GI \times VAR}{1-(GI - GI \times VAR)} = NI,$$

or in a simpler notation.

$$\text{(5b)} \qquad \frac{VAR}{\frac{1}{GI} - (1 - VAR)} = NI.$$

Applying this to the above treated case of Industry 1b with 50% *VAR*, we have

$$\text{(6)} \qquad \frac{.50}{\frac{1}{1.0476} - (1-.50)} = \frac{.50}{.45456} = 1.10,$$

which is the expected rate of net productivity change.

Such index differences sometimes have striking consequences. An extreme example is in the American poultry industries, where purchased feed dominates the inputs and value added is a small fraction of total turnover. In the 1950s and 1960s, these activities expanded vigorously and the relative prices of eggs and chicken meat fell sharply, yet gross productivity rose only slowly (Dovring, pp. 35 ff).

A large case in point is in gross productivity for American agriculture, as computed for the years 1940–57. According to Loomis and Barton (p. 1), in those years "agricultural productivity increased at an average annual rate of 1.6 percent, compared with 2.3 percent for the economy as a whole." In net productivity, agriculture comes out ahead of the national economy.

Use of gross productivity can thus lead to misjudgment of the performance of a sector. This points to the special roles the various productivity measurements can play. Gross productivity is necessary for analysis of the causation of productivity change but is misleading as to rate of change, unless the index is corrected in the way suggested above. Net productivity is comparable between sectors but leaves some uncertainty as to what it is we measure.

By the same criterion (of purpose of analysis), the single-factor productivity measures will have continuing roles to play in addressing distinct problems. They also have the advantage of being simpler and less beset with conceptual problems. Use of aggregated-labor productivity did elude most of the index-number problems and showed some economically meaningful relation to trends of relative output prices. Before 1973, the price of labor was the single most important issue for which productivity analysis could be undertaken. For the future, we have to count upon rising prices of energy—above all the capital costs of the energy industries—and so it will now be important to watch the energy-productivity performance of the food and fiber complex, which can be pursued by techniques similar to those of aggregated-labor productivity analysis.

[*Received April 1977; revision accepted January 1979.*]

References

Christensen, Laurits R. "Concepts and Measurement of Agricultural Productivity." *Amer. J. Agr. Econ.* 57 (1975):900–15.

Dovring, Folke. *Productivity of Labor in Agricultural Production.* University of Illinois Agr. Exp. Sta. Bull. 726, Sept. 1967.

Fabricant, Solomon. "Basic Facts on Productivity Change." National Bureau of Economic Research Occ. Pap. No. 63, New York, 1959.

Griliches, Zvi. "The Sources of Measured Productivity Growth, U.S. Agriculture, 1940–60." *J. Polit. Econ.* 71(1963):331–46.

Horring, J. *Concepts of Productivity Measurement in Agriculture on a National Scale*. Paris: O.E.C.D., 1962 (O.E.C.D. Documentation in Food and Agriculture 57).

Howe, Eric C., and Charles R. Handy. "Inventory and Critique of Productivity Estimates in the U.S. Food and Fiber Sector." *Amer. J. Agr. Econ.* 57 (1975):916–21.

Hulten, Charles R. "Technical Change and the Reproducibility of Capital." *Amer. Econ. Rev.* 65 (1975):956–65.

Loomis, Ralph A., and Glen T. Barton. *Productivity of Agriculture. United States, 1870–1958*. USDA Tech. Bull. No. 1238, 1961.

Pasinetti, Luigi L. "On Concepts of Measures of Changes in Productivity." *Rev. Econ. and Statist.* 41 (1959):270–82.

Ruttan, Vernon W. "Technological Progress in the Meatpacking Industry 1919–47." USDA Mktg. Res. Rep. No. 59, 1954.

———. "Agricultural and Nonagricultural Growth in Output per Unit of Input." *J. Farm Econ.* 39 (1957):1566–76.

A Spatial Model of Land Market Behavior

Leroy J. Hushak and Kazem Sadr

This paper presents results of an application of a transcendental function in the analysis of land market behavior. The assumption of featureless space in the Von Thunen model is dropped and characteristics of the space hypothesized to affect land prices are incorporated (Hushak 1977, Sadr). Results are presented for three different areas for which land transactions data have been collected. The availability of three separate data sets allows examination of alternative mathematical specifications across, as well as within, data sets. Based on pretest estimation criteria discussed by Wallace, the ability to cross-test alternative models on different data sets provides stronger criteria for model selection.

In log form, the transcendental relationship determining land prices over space is

$$(1)\ \text{Log}price = a_0 + a_1\ \text{Log}size + a_2\ Real\ Tax\ Rate + a_3 \frac{Taxable\ Building\ Value}{Total\ Taxable\ Value} \Sigma\, b_i x_i + e,$$

where price is price per acre, size is acres in the land parcel, real tax rate is the property tax rate multiplied by the ratio of taxable value to price, taxable building value/total taxable value is the control for buildings, the x_i's are other parcel characteristics, and e is the random disturbance. The coefficient a_1 is a price flexibility (the inverse of the price elasticity of demand) providing the estimated percentage of change in price per acre for a 1% change in parcel size. Its expected sign is negative and it must be less than one in absolute value (elastic) for total parcel price to increase with size.

The coefficients a_2, a_3, and b_i yield constant changes in the log of price per unit change in the variables, which approximate constant percentage changes for values of less than 10%.[1] These constant log changes result in greater arithmetic price changes as price increases. The coefficient a_2 is expected to be negative, while a_3 is expected to be positive and about 2%. Each one percentage point increase in taxable building value/total taxable value is accompanied by a one percentage point decline in taxable land value/total taxable value.

Factors x_i include measures of distances from urban centers, distances from transportation arteries, and land use activities.[2] The expected relationships for these variables are detailed elsewhere, in particular Hushak (1975), and are not repeated here.

The Transcendental Function

Most previous studies have used an arithmetic function, but with a number of modifications. Arithmetic functions tend to fit well in those studies using aggregate data, e.g., Hammill, Pasour (1973, 1975), and Schuh and Scharlach. However, several problems arise when arithmetic functions are fitted to microdata, e.g., Clonts, Downing, and Hushak (1975). First, the relationship between per unit price and parcel size is highly nonlinear. One reason is that the cost of subdividing land parcels is approximately constant, and this cost is spread over less area as parcel size declines. Hushak (1975) incorporated this nonlinear relationship by using the reciprocal of parcel size as a variable.

Second, an arithmetic function imposes an inconsistent relationship between property tax rates and per unit land prices. Conceptually, the expected impact of a unit change in the property tax rate is negative and proportional to land price. The arithmetic function imposes a constant change in per unit land price regardless of the price level. At best, an average impact for the sample can be estimated. The use of the log of the property tax rate by Pasour (1973) does not resolve this inconsistency. Lacanere used an exponential function, i.e., log price as the dependent variable, to obtain a consistent relationship, but retained the reciprocal of parcel size as an explanatory variable. Hepner, Lewis, and Muraco used a transcendental function, which sub-

Leroy J. Hushak is a professor at Ohio State University and the Ohio Agricultural Research and Development Center, and Kazem Sadr is an assistant professor at Pahlavi University, Shiraz, Iran.

Approved for publication as Journal Article No. 56–78 of the Ohio Agricultural Research and Development Center.

Helpful comments by E. Dean Baldwin, Kenneth C. Clayton, E. C. Pasour, Jr., F. E. Walker, and the anonymous *Journal* reviewers are gratefully acknowledged. The authors are responsible for any remaining errors or omissions.

[1] For larger changes, the constant change in log price using base e is converted to percentage of change by $(e^{b_i} - 1) \times 100$.

[2] Local government expenditures and topographical characteristics are two additional sets of variables which may affect land prices. For given property tax rates, local government expenditures are expected to be positively related to land prices (Tiebout). When included in two data sets, local government expenditure variables did not have expected signs or high t-ratios. Crude information on some topographical characteristics was obtained for part of one data set. When included, the coefficients of topographical variables had expected signs and significant t-ratios. These results are not presented here because they were available for only part of one data set and their inclusion had no effect on coefficients of included variables.

stitutes the log of parcel size for parcel size and its reciprocal in the exponential function.

The transcendental function also provides a consistent means of controlling for the contribution of buildings to land prices with taxable building value/total taxable value. The taxable values are the values applied to land and buildings for property tax purposes. Because most parcels in the data sets contain buildings, a means of controlling for the impact of these improvements on land prices is needed.

Theory does not provide a basis for preferring one function over the other with respect to the other factors, x_i. Downing found that reciprocals of distance variables yielded better fitting results than linear distance variables. In this study, the statistical consistency and significance of the estimated coefficients of the x_i in the transcendental function (1) are much greater than for either the arithmetic function or for an alternative transcendental function which used the logs of the distance variables.

Preliminary estimates of several alternative models were obtained. One alternative used price per acre times taxable land value/total taxable value as the dependent variable. This formulation, which provides an alternative specification to control for building values, gives similar results. In addition, estimates from subsamples of each data set were obtained. Under all alternative formulations, the estimated coefficients of the transcendental function are similar to the results presented. The results from alternative specifications are not similar within or across data sets.

Description of Study Areas and Data Sets

Two of the three Ohio study areas are metropolitan areas. Columbus had a metropolitan (SMSA) population of 916,228 in 1970, a 21% increase over 1960 population. The city of Columbus had a 1970 population of 540,025, an increase of 14.6% over 1960. Dayton had a metropolitan population of 850,266 in 1970, an increase of 17% from 1960, but the city of Dayton had a 7.4% population decrease from 1960 to 242,917 in 1970. The third area consists of five rural counties in southeast Ohio (SE Ohio): Athens, Gallia, Jackson, Meigs, and Vinton. The 1970 population of this area was 136,521, an increase of 0.7% over 1960. Population increased only in Athens County; the remaining four counties had declines. All counties have participated in the "population turnaround" since 1970 (Beale). The estimated five-county 1976 population was 141,400, a 3.6% increase over 1970 (Bureau of the Census).

Each data set is a stratified random sample of "arms-length," or open market, cash transactions. The Ohio Board of Tax Appeals separates all land transactions into usable and nonusable transactions. The usable group includes all transactions where the recorded price of the land parcel exchanged is expected to represent an unencumbered market price. Examples of nonusable transactions are exchanges between related individuals and sales to settle estates. All observations for this study came from the set of usable transactions, which are expected to be open market, cash transactions.

The Columbus and Dayton data sets were stratified on the basis of land area; the SE Ohio data set was selected by stratifying 50% of the sample on the basis of land area and 50% on the basis of population. The data sets were further stratified by use; nearly all transactions of agricultural and commercial property were obtained. The objective of these stratification procedures was to obtain a sufficient number of parcels by type and throughout the study areas for reliable statistical estimation. The samples are not representative of types of land transactions in the study areas.

Characteristics of the three data sets are presented in table 1. The Columbus and Dayton study areas included all townships with more than 50% of their land area within a 25-mile radius of the central business districts. For Columbus, all of Franklin County, in which Columbus is located, and parts of the six adjacent counties are included. Platted land parcels were excluded, but land parcels within the boundaries of Columbus and other incorporated cities and municipalities were included if unplatted.

For Dayton, all of Montgomery County, in which Dayton is located, and parts of the seven adjacent counties are included. Excluded were platted parcels and parcels within Dayton and other incorporated cities and municipalities (in contrast to Columbus). Also, special controls for the impact of Springfield were developed because Springfield is a relatively large urban center near Dayton. The SE Ohio data set includes parcels from all parts of the study area, platted and unplatted, within as well as outside of incorporated municipalities. There are an approximately equal number of observations for each of the five years.

The summary characteristics in table 1 are highly dependent on the structure of each data set. The high mean values of price per acre for commercial and residential transactions in the SE Ohio data set are due to the inclusion of central business district commercial transactions and platted residential transactions, both of which are improved and have relatively high building values. Taxable building value/total taxable value is highest for this data set. The real tax rate is similar (perhaps surprisingly) for the three data sets.

Results

In the estimation of equation (1) *log price* is the log of the total value of the transaction per acre; *log size* is the log of the acres in the land parcel; *use* is a set of two dummy variables with residential use as the control group—*commercial* = 1, land use is commercial, industrial, or multiple-unit dwelling, 0

Table 1. Characteristics of Sample Land Parcels

	Columbus 1972	Dayton 1974	SE Ohio 1970–74
Price/acre ($)			
Total sample	14,881[a]	32,206	69,682
	(20,275)	(39,564)	(297,657)
	[225]	[274]	[1,341]
Commercial	27,641	38,036	196,105
	(34,965)	(39,564)	(551,916)
	[14]	[22]	[349]
Residential	17,771	27,145	46,782
	(19,724)	(20,607)	(93,626)
	[164]	[204]	[531]
Agricultural	997	2,208	349
	(1,199)	(2,834)	(1,043)
	[47]	[48]	[461]
Parcel size (acres)			
Total sample	18.9	11.8	27.4
	(45.8)	(28.64)	(62.3)
$\frac{\text{Taxable building value}}{\text{Total taxable value}}$	0.50	0.52	0.57
	(0.36)	(0.35)	(0.32)
Real tax rate	11.62	11.35	10.03
	(6.81)	(5.39)	(5.29)

[a] Mean with standard deviation in parentheses and number of observations in brackets.

otherwise; *agriculture* = 1, land use is agriculture, 0 otherwise. *Log size-comm* is log size multiplied by the qualitative variable, commercial; *log size-agr* is log size multiplied by the qualitative variable for agriculture; *real tax rate* is property tax rate multiplied by $\frac{\textit{total taxable value}}{\textit{total value of transaction}}$ (mills); *real tax-comm* is real tax rate multiplied by commercial; *real tax-agr* is real tax rate multiplied by agriculture; $\frac{\textit{taxable building value}}{\textit{total taxable value}}$ is the ratio of taxable building value to total taxable value; *distance urban center* is the direct line distance in miles from the nearest city hall or major shopping center (Columbus, Dayton); *location Springfield* = 1, land parcel located within fifteen road miles of Springfield, 0 otherwise (Dayton); *distance Springfield* is road distance from Springfield if location Springfield = 1, 0 otherwise (Dayton); *distance second city* is the direct line distance in miles from nearest city with population of more than 10,000 including urban center (Columbus, Dayton); *location* is a set of two dummy variables in the SE Ohio data set with land parcels located closer to the city of Gallipolis than to Athens or Jackson as the control group; *location Athens* = 1, land parcel is closer to Athens than to Gallipolis or Jackson, 0 otherwise; *location Jackson* = 1, land parcel is closer to Jackson than to Athens or Gallipolis, 0 otherwise; *distance Gallipolis* is the direct line distance in miles from Gallipolis if Gallipolis is nearest city, 0 otherwise (SE Ohio): *distance Athens* is the direct line distance in miles from Athens if location Athens is 1, 0 otherwise (SE Ohio); *distance Jackson* is the direct line distance in miles from Jackson if location Jackson is 1, 0 otherwise (SE Ohio); *distance municipality* is the direct line distance in miles from the nearest incorporated municipality of any size including cities; and *disturb-comm* is distance urban center multiplied by commercial (Columbus, Dayton). Continuing: *railroad* = 1, land located within 0.6 mile of a railroad for Columbus and Dayton or within one mile of a railroad for SE Ohio, 0 otherwise; *rail-comm* is railroad multiplied by commercial; *distance highway* is the road distance in miles from the nearest major highway (major city streets, state and U.S. highways, and interstate highways); *highway-comm* is distance highway multiplied by commercial (SE Ohio); *county* = 0, land parcel in central urban county, 1, land parcel not in central urban county (Columbus, Dayton). The variables *log size-comm, log size-agr, real tax-comm, real tax-agr, disturb-comm,* and *highway-comm* are introduced to allow differential responses of land prices by land use.

Estimates of equation (1) for each data set are presented in table 2. The *F*-ratio for each equation is highly significant. Each equation contains a large number of variables. In the present analysis, the potential increase in variance from the inclusion of extraneous variables appears less costly than the potential bias from false restrictions (Wallace, pp. 432–33).

The coefficients of log size are price flexibilities for changes in parcel size. For Columbus, the estimated price flexibilities are −0.638 for residential, −0.393 for commercial, and −0.176 for agricultural

Table 2. Estimated Land Price Relationship for Three Land Market Areas

	Columbus	Dayton	SE Ohio[a]
Log size	−0.638	−0.645	−0.834
	(19.00)	(25.57)	(34.27)
Log size-comm	0.245	0.202	0.091
	(2.57)	(3.05)	(2.85)
Log size-agr	0.462	0.327	0.443
	(6.18)	(5.39)	(11.44)
Real tax rate	−0.045	−0.045	−0.070
	(7.39)	(6.09)	(11.96)
Real tax-comm	−0.011	−0.010	0.019
	(0.93)	(0.65)	(2.20)
Real tax-agr	−0.031	−0.047	−0.017
	(2.58)	(3.16)	(1.93)
Use			
Commercial	0.412	1.353	0.614
	(1.03)	(5.15)	(5.45)
Agriculture	−1.030	−0.541	−1.067
	(3.61)	(1.93)	(6.91)
Taxable building value / Total taxable value	2.145	1.980	1.958
	(22.06)	(19.80)	(29.16)
Distance urban center	−0.036	−0.044	
	(3.55)	(3.56)	
Location Springfield		0.571	
		(1.51)	
Distance Springfield		−0.025	
		(0.79)	
Distance second city	−0.011	−0.039	
	(1.27)	(3.46)	
Distance Gallipolis			−0.023
			(3.72)
Location Athens			0.482
			(4.78)
Distance Athens			−0.049
			(8.88)
Location Jackson			−0.077
			(0.75)
Distance Jackson			−0.007
			(1.03)
Distance municipality	−0.039		
	(2.16)		
Dist urb-comm	−0.051	−0.100	
	(1.49)	(3.60)	
Railroad	−0.131		0.153
	(1.86)		(2.98)
Rail-comm	0.793		
	(2.70)		
Distance highway	−0.069	−0.033	−0.031
	(2.71)	(1.15)	(1.81)
Highway-comm			−0.272
			(2.98)
County	−0.177	0.017	
	(1.63)	(0.20)	
Intercept	9.502	9.884	8.994
	(72.00)	(75.40)	(65.39)
R^2	0.928	0.919	0.950
F	157	182	857
Observations	225	274	1341

Note: t-ratios in parentheses.
[a] Variables included in this equation with coefficients not presented are location in townships or municipalities versus the three largest cities, platting of and number of parcels per transaction, proximity to airports, parks and the Ohio River, and year of transaction.

parcels. All price flexibility coefficients are less than one in absolute value, implying price elasticities of demand for parcel size which are elastic. The relatively higher price flexibility coefficients for residential and commercial parcels in SE Ohio are partially explanable by the rough topography of the

region, with the result that a larger parcel is more likely to include land which is not usable unless significant costs are incurred.

The main difference in the real tax coefficients is the relatively high capitalization rate for residential parcels in SE Ohio of 7% as compared to 4.5% for Columbus and Dayton. This may be due to a relatively greater burden of the property tax on residential property in SE Ohio compared to Dayton and Columbus. Estimates based on subsamples of the SE Ohio data set indicate it is not caused by the inclusion of platted parcels. At the same time the estimated capitalization rates for commercial (5.1% to 5.6%) and agricultural (7.6% to 9.2%) parcels are of similar magnitude.

The coefficients of the use variables show that commercial and agricultural parcels in the Dayton area are priced higher relative to residential parcels than in Columbus or SE Ohio. While the Dayton and Columbus areas are similar in the extent of zoning ordinances, the use coefficients for Columbus are similar to those of SE Ohio which has very few zoning or other land use controls in force.

Land prices in all three areas respond to location variables. For Columbus and Dayton, land prices decline by about 4% for each additional mile from the urban center. Both urban cities are multicentered; Hepner, Lewis, and Muraco found similar results for Toledo. Large retail-industrial centers in the fringe areas of both Columbus and Dayton have stronger impacts on land prices than the central business districts. In both areas, distance from central business district is not significantly related to land prices. A multicentered concept is required. Land prices in both urban centers also respond to distance from smaller municipalities. In Dayton, cities of 10,000 or more population had a relatively stronger impact than smaller municipalities, while in Columbus smaller municipalities were relatively more important.

For SE Ohio, the urban center measures had to be structured differently because there is not a dominant urban center. Athens, with a 1970 population of about 24,000, is the largest center; Gallipolis and Jackson both have populations of less than 10,000. The coefficient of *location Athens* suggests that Athens is the strongest point of attraction in the five county area. Distances from Athens and Gallipolis both have negative and significant coefficients. While distance Jackson does not have a significant coefficient, this result may be due to Wellston, a city about three-fourths of the size of Jackson and only six miles from Jackson.[3] Distance from smaller municipalities did not affect land prices in this relatively rural region. However, coefficients of the two variables not shown in table 2 indicating whether land is located in a township or municipality relative to the three cities had high t-ratios and showed that land located in townships had the lowest price, followed by municipalities and the three cities.

The price of commercial parcels declines more rapidly with increasing distance from urban center than residential or agricultural parcels. In SE Ohio, where there are no urban centers, nearly all commercial parcels were in or near a municipality, and there are few major highways, a significant interaction between distance to highway and commercial parcels was found. Other variables were included in the SE Ohio data set to control for the inclusion of all types of land parcels and unique characteristics of the area. The coefficients of these variables generally conformed to conceptual expectations.

Conclusion

While there are differences in coefficients and differences in the general level of land prices across areas, the overall response of land prices to spatial characteristics with the transcendental model is remarkably similar across the three land market areas. The transcendental model provides relatively stable results, both within and across data sets. The two most critical specification issues are: (a) obtaining a consistent relationship between land price and the real tax rate and building value control variables which imply a nonarithmetic scaling of the price variable such as log price, and (b) allowing for nonlinear relationships with other variables, in particular parcel size. Arithmetic functions do not satisfy these conditions and result in different price response estimates, not only across data sets, but within data sets across alternative model specifications and subsamples of data.

[*Received April 1978; revision accepted May 1979.*]

[3] If Wellston has a larger impact on land prices than other incorporated municipalities, then the price of land parcels in or near Wellston but at some distance from Jackson will bias the coefficient of distance Jackson toward zero.

References

Beale, Calvin L. "A Further Look at Nonmetropolitan Population Growth Since 1970." *Amer. J. Agr. Econ.* 58(1976):953–58.

Clonts, Howard A., Jr. "Influences of Urbanization on Land Values at the Urban Periphery." *Land Econ.* 46(1970):489–97.

Downing, Paul B. "Factors Affecting Commercial Land Values: An Empirical Study of Milwaukee, Wisconsin." *Land Econ.* 49(1973):44–56.

Hammill, Anne E. "Variables Related to Farm Real Estate Values in Minnesota Counties." *Agr. Econ. Res.* 21(1969):45–50.

Hepner, George F., Donald W. Lewis, and William A.

Muraco. "Locational Factors and the Demand for Land on the Rural Urban Fringe of Toledo, Ohio." Business Research Center Rgnl. Res. Rep. No. 10, University of Toledo, Oct. 1976.

Hushak, Leroy J. "The Urban Demand for Urban-Rural Fringe Land." *Land Econ.* 51(1975):112–23.

———. "The Urban Demand for Urban-Rural Fringe Land: Reply." *Land Econ.* 53(1977):131–32.

Lacanere, Anthony M. "An Economic Analysis of the Urban-Rural Fringe Land Market: An Empirical Study of Dayton, Ohio." M.S. thesis, Ohio State University, 1975.

Pasour, E. C. "The Capitalization of Real Property Taxes Levied on Farm Real Estate." *Amer. J. Agr. Econ.* 57(1975):539–48.

———. "Real Property Taxes and Farm Real Estate Values: Incidence and Implications." *Amer. J. Agr. Econ.* 55(1973):549–56.

Sadr, Kazem. "Land Use Analysis in a Developing Region: A Study of a Five County Region in Southeast Ohio." Ph.D. thesis, Ohio State University, 1976.

Schuh, G. Edward, and Wesley C. Scharlach. "Qualitative Analysis of Some Farm and Non-Farm Determinants of Agricultural Land Values—Impact of Economic Development." Purdue Agr. Exp. Sta. Bull. No. 821, Nov. 1966.

Tiebout, Charles M. "A Pure Theory of Public Expenditures." *J. Polit. Econ.* 64(1956):416–24.

U.S. Department of Commerce, Bureau of the Census. "Estimates of the Population of Ohio Counties and Metropolitan Areas: July 1, 1975 (Revised) and 1976 (Provisional)." *Current Population Reports,* Ser. P-26, No. 76-35, Dec. 1977.

Von Thunen, Johann H. *Von Thunen's Isolated State,* tr. Carla M. Wartenburg. London: Oxford University Press (original 1826), 1966.

Wallace, T. Dudley. "Pretest Estimation in Regression: A Survey." *Amer. J. Agr. Econ.* 59(1977):431–43.

Accuracy of Least Squares Computer Programs: Another Reminder: Comment

J. C. Nash

In a recent issue of this *Journal*, Boehm, Menkhaus, and Penn present yet another warning concerning the accuracy of least squares programs. While their warning is valid and useful, the recommendations to users in the authors' conclusions are, at the very least, tedious. This is especially so when users have access to highly effective methods for coping with ill-conditioned data in least squares problems. This comment examines each of the recommendations of Boehm, Menkhaus, and Penn in the light of what can be done with a singular value decomposition algorithm, in particular demonstrating that this technique reveals collinearities and permits some assessment to be made of their seriousness. Statistical computing packages, for instance the TROLL system of the National Bureau of Economic Research, are beginning to incorporate such methods. While most packages do obtain reasonable answers to the least squares problems they attempt to solve, doubts can only be set aside if the computing techniques employed are able to reveal the structure of the problem. That such techniques are not more widely used is largely a matter of imperfect exchange of information between researchers in different disciplines, a fault which this note will try in part to correct.

In the following sections the recommendations of Boehm, Menkhaus, and Penn are reviewed. The difficulties which may be inherent in linear least squares problems are then outlined briefly in the light of principal components solution methods. The family of computational procedures based on the singular value decomposition of a matrix is recommended as a practical way to implement such methods, which provide valuable information about the numerical stability of the regression problem whether or not principal components estimators are desirable from a statistical point of view.

The fractional variation and explanation indices f_i and E_i presented below are, it is believed, novel. The rest of the material is a summary of ideas taken from several sources outside the literature commonly consulted by economists.

J. C. Nash is an economist with the Policy, Planning & Economics Branch, Agriculture Canada, Ottawa.

The author would like to acknowledge discussions with Z. Hassan and G. MacAulay pertinent to the preparation of this note. The development of equations (13) to (17) was suggested by the referee.

Recommendations

In summary, Boehm, Menkhaus, and Penn suggest (*a*) that least squares computer programs be tested by use of the Wampler problems generated by

$$(1)\qquad y_j = \sum_{i=0}^{5} j^i \quad \text{for} \quad j = 0, 1, \ldots, 20.$$

$$(2)\qquad y_j = \sum_{i=0}^{5} (0.1j)^i \quad \text{for} \quad j = 0, 1, \ldots, 20.$$

These polynomial least squares problems have no error term so should yield coefficients of 1 and $(0.1)^i$, respectively, for the powers of j when solved by least squares. It can be proved that power terms are linearly independent. Unfortunately, powers have the property of being "nearly dependent," which causes trouble in polynomial least squares. That is, due to the nature of floating-point arithmetic, it is unlikely that the computed regression matrix X defined by (1) or (2), whose elements are approximations to j^i or $(0.1j)^i$, can be distinguished in any practical way from a similarly approximated matrix which has columns known to be linearly dependent. Because linear dependence implies that at least one linear combination of the columns is null, then, given a set of regression coefficients that minimizes the residual sum of squares, one can obtain an infinity of regression solutions by adding arbitrary components of the null linear combination of columns. A given program operating in a specified environment will calculate an approximation to one of these solutions corresponding to a residual sum of squares very near the minimum—in the present case zero—hence an R^2 approaching 1 for the problems at hand. Thus, in the examples given by Boehm, Menkhaus, and Penn, nearly all the programs tested have succeeded in finding a solution which "explains" the data to the extent that the calculated R^2 is given as 1. That the residual sums of squares are not zero is very likely a result of the use of the formula

$$(3)\qquad S = \mathbf{y}^T\mathbf{y} - \mathbf{y}^T X\beta,$$

which obtains the sum of squares S by subtraction of nearly equal magnitudes. In this expression, X is the matrix for which element X_{ij} is the ith observation of the jth variable or the constant, $\mathbf{y}$ is the vector of observations on the dependent variable and β is

the vector of regression coefficients with T denoting matrix transposition. The use of equation (3) is unnecessary, because even in the case where the number of observations m is large, there is no need to calculate the residuals r via the formula

(4) $$\mathbf{r} = \mathbf{y} - X\beta$$

in order to be able to compute S as a genuine sum of squared terms (Nash and Lefkovitch). For problem (1), the quantity $\mathbf{y}^T\mathbf{y}$ is of the order of 10^{13}, while the sum of the squares of the elements of the constant column has the value 21. In IBM and Xerox machines the single precision mantissa consists of just six hexadecimal digits. (At the installations with which the author is acquainted, IBM and Xerox machines are identical in this respect, in contrast to a statement of Boehm, Menkhaus, and Penn.) Thus, addition or subtraction of these numbers cannot be carried out in such arithmetic without loss of information. It is hardly surprising, then, that while R^2 approximates 1, S is not zero in all cases cited.

The authors suggest (*b*) that parameters should be reestimated using alternative routines prior to publication or use. For problems (1) and (2), and a large class of real problems, different routines give different parameters. Such variation may be an indication that further investigation is necessary. However, the converse, that is the case where two programs give similar results, gives no assurance that the parameters so obtained are more trustworthy than any others. The approach outlined below is capable of alerting the user to the possibility of large program-to-program parameter differences while allowing a set of parameters to be computed.

Boehm, Menkhaus, and Penn also suggest (*c*) that calculations be performed using scaled or otherwise adjusted data. Certainly for regressions involving a constant term, adjusting variables by subtraction of means is helpful in reducing the loss of information which attends the formation of the normal equations

(5) $$X^TX\beta = X^T\mathbf{y}.$$

However, repetition of calculations is costly and, by and large, unnecessary. Perturbation of the data is useful for discovering sensitivity of the parameters to small changes, but can equally be determined internally in a single calculation as mentioned later. To do a proper job of a perturbation analysis, one must follow the lead of Beaton, Rubin, and Barone, who ran 1,000 sets of perturbed data through the program DORTHO, which was chosen for its reputed accuracy. They compared the distributions of the parameters with the parameters obtained from the unperturbed data using DORTHO and conclude that a highly accurate solution to the unperturbed problem may be far from the center of the distribution. In fact, while the perturbations were at most ± 0.5 in the last published digit of the data of Longley, only 2% of the solutions agreed with the unperturbed solution to one or more digits. Beaton, Rubin, and Barone show that even the Worst Algorithm You Are Likely to Get (*WRYALG*) performs comparatively well on a more stable problem. They propose a "perturbation index" calculable from the independent variables together with some information concerning the error of measurement of these variables.

Finally, the authors suggest (*d*) that the ordering of the variables in the regression be changed. Changing the order of the variables does have some influence on the rounding errors incurred in solving least squares problems (see the examples in table 1). However, it should only cause severe changes

Table 1. Results of Several Methods for Wampler Problems (1) and (2)

Program	ENHSVA	ENHNLR	ENHCRR	ENHCRR	ENHSVA
Variable order	5,4,3,2,1,0	1,2,3,4,5,0	5,4,3,2,1[a]	1,2,3,4,5[a]	1,2,3,4,5,0
Problem (1)					
β_0	0.899267	0.973972	−196.59	29500.1	0.905485
β_1	1.03452	0.973972	272	128	0.884127
β_2	0.987797	1.00508	−216	256	0.838069
β_3	1.00157	1.00007	34	−48	1.04047
β_4	0.999936	0.999974	−0.625	2.75	0.997045
β_5	1	1	1.02344	0.960938	1.00007
Residual SS	0.692156	0.141761	2.9214E+7	3.37718E+10	10.5361
R^2	1	1	0.999998	0.998205	1
Problem (2)					
β_0	0.999996	1	0.661053	1.20079	1
β_1	0.100003	9.99985E-2	0.111328	0.103516	9.99969E-2
β_2	9.99884E-3	1.00006E-2	6.22559E-3	1.17188E-2	9.9964E-3
β_3	1.00018E-3	9.99905E-4	1.61743E-3	6.10352E-4	1.00089E-3
β_4	9.99884E-5	1.00006E-4	6.91414E-5	1.2207E-4	9.99342E-5
β_5	1.00002E-5	1.00004E-5	1.08629E-5	9.29832E-6	1.00015E-5
Residual SS	1.19889E-9	9.46799E-11	3.79384	2.04144	8.79328E-9
R^2	1	1	0.999425	0.999691	1

[a] Constant is implicit.

in the results for very ill-conditioned systems, which in any event our methods should aim to detect.

The Linear Least Squares Problem

The linear least squares problem is stated: given a set of m values y_i ($i = 1, 2, \ldots, m$) and an m by n matrix X, minimize the sum of squares

$$Z = \sum_{i=1}^{m} \left(y_i - \sum_{j=1}^{n} X_{ij}\beta_j\right)^2 = \mathbf{r}^T\mathbf{r}, \tag{6}$$

with respect to the parameters β_j($j = 1, 2, \ldots, n$). While it is usually presumed that the problem has a unique solution, this is not always the case. It is the author's experience that problems whose computer representation is practically indistinguishable from the representation of a rank-deficient problem are quite common. For such problems a large number of vectors β will yield a computed residual sum of squares within some small tolerance of the minimum. Moreover, these vectors may exhibit very large differences if compared one with another. If a given program in a specified computer system calculates one of these least squares solutions, it has done its job. Far from leaving "the applied researcher with a feeling of helplessness," as Boehm, Menkhaus, and Penn have suggested, this merely implies that at least one of the columns of X is in some sense redundant in explaining $\mathbf{y}$. Furthermore, the degree to which such redundancy, or linear dependence, poses a difficulty depends largely on the application for which the least squares problem is solved.

For instance, one may be interested in computing the value of certain linear combinations of the coefficients β, of which predictions of y values are but one example. Such estimable functions will not depend on the particular set of coefficients β chosen—a choice made either consciously or by the sequence of arithmetic operations implied by the program and computer used.

Detecting linear dependencies or multicollinearity is not usually difficult, though Boehm, Menkhaus, and Penn are correct in warning that packaged programs may fail to take advantage of the known techniques. (Here a narrow definition of collinearity is used, that is, that X is computationally rank deficient to some specified precision.) In the face of commonly available regression programs, suggestions (*c*) and (*d*) above are probably the only means by which ill-conditioned problems may be detected, though such exercises can be systematized by methods similar to that of Mullet and Murray. Linear dependence among the independent variables in a regression corresponds to singularity of the matrix X^TX in the normal equations (5). The usual condition that the determinant of a singular matrix is zero is of little practical value in detecting singularities since the computed value of the determinant of a singular matrix may still be "large." The eigenvalues of X^TX, or better their square roots, which are the singular values of X (see Lawson and Hanson), provide a much better tool. Moreover, they can be computed as a step in finding the least squares solution and furnish a method by which principal components solutions may be calculated (Nash 1974). In one modification (Nash and Lefkovitch) such procedures allow the computation of uncorrelated residuals (Grossman and Styan) and permit regression calculations to be sequentially updated by additional observations. Lawson and Hanson discuss several similar techniques. Ideas along the same lines using the eigenvalues of X^TX are presented by Webster, Gunst, and Mason.

In essence, the technique proposed is to form the singular value decomposition (svd) of the matrix X, that is,

$$X = USV^T, \text{ where} \tag{7}$$

$$V^TV = VV^T = I_n, \tag{8}$$

where I_n is the identity matrix of order n, and

$$U^TU = I_n. \tag{9}$$

In the decomposition U will be taken to be m by n, S n by n and diagonal containing the (positive) singular values, and V n by n. The reader should note that other forms exist which are equivalent, for instance with U m by m and S m by n with rows n + 1 to m null, and that the form chosen may affect certain details in the presentation. When the matrix X has linearly dependent columns, one or more of the singular values S will be zero. Then, in order to avoid the difficulty presented by the existence of an infinity of solutions, extra conditions must be imposed on β. One such condition is that in addition to minimizing the residual sum of squares Z, β should minimize

$$\beta^T\beta = \sum_{j=1}^{n} \beta_j^2, \tag{10}$$

thus giving the minimum length least squares solution. It can be shown (see, for instance, Nash 1974 or Lawson and Hanson, chap. 7) that the minimum length least squares solution is given by

$$\beta^* = X^+\mathbf{y} = VS^+U^T\mathbf{y}, \tag{11}$$

where S^+ is the diagonal matrix

$$\begin{aligned} S_{ii}^+ &= 1/S_{ii} \quad \text{for} \quad S_{ii} > 0, \\ &= 0 \qquad\;\;\, \text{for} \quad S_{ii} = 0. \end{aligned} \tag{12}$$

The matrix X^+ as defined by (11) and (12) is the Moore-Penrose generalized inverse of X (Rao and Mitra). Substitution of the singular value decomposition into the normal equation (5) gives

$$VS^2V^T\beta = VSU^T\mathbf{y}, \tag{13}$$

which is easily transformed to

$$S^+SV^T\beta = S^+U^T\mathbf{y}. \tag{14}$$

From (12) it is obvious that if $(n - k)$ of the singular values S_{ii} are zero, only $k = \text{rank}(X)$ of the equation (14) place conditions on β, the rest being null. The matrix $(I_n - S^+S)$ has ones on the diagonal positions corresponding to these null equations and zeros elsewhere. The elements of $V^T\beta$ corresponding to the null equations are thus given by the nonzero components of $(I_n - S^+S)V^T\beta$. However, the values of these elements are arbitrary. Let them be given by

$$(I_n - S^+S)V^T\mathbf{e},$$

where $\mathbf{e}$, hence $V^T\mathbf{e}$, is an arbitrary vector. Therefore,

$$(15) \qquad (I_n - S^+S)V^T\beta = (I_n - S^+S)V^T\mathbf{e}.$$

Combining (14) and (15),

$$(16) \quad S^+SV^T\beta + (I_n - S^+S)V^T\beta = S^+U^T\mathbf{y} + (I_n - S^+S)V^T\mathbf{e}, \qquad \text{or}$$

$$(17) \qquad \beta = VS^+U^T\mathbf{y} + (I_n - VS^+SV^T)\mathbf{e} = X^+\mathbf{y} + (I_n - X^+X)\mathbf{e}.$$

Equation (17) gives the general expression for the ordinary least squares solution in both full-rank and rank-defective situations. Furthermore, the svd shows a way to compute least squares solutions in this form, at the same time allowing one to identify collinearities.

Principal Components Regression

Henceforth we shall assume that the matrix S is ordered so that

$$(18) \qquad S_{ii} \geq S_{jj} \quad \text{for} \quad i < j.$$

Thus, the matrix of principal components,

$$(19) \qquad B = XV = US,$$

has columns (the components) with decreasing size from left to right. That is, the first column explains the largest proportion of the variation of the independent variables, the second column the next largest proportion, and so on. However, when we regress on the principal components, that is, solve the least

$$(20) \qquad \text{minimize } Z = (\mathbf{y} - B\mathbf{w})^T(\mathbf{y} - B\mathbf{w}),$$

with respect to $\mathbf{w}$, the normal equations

$$(21) \qquad B^TB\mathbf{w} = S^2\mathbf{w} = B^T\mathbf{y}$$

have a minimum length solution

$$(22) \qquad \mathbf{w} = S^+U^T\mathbf{y} = (S^+)^2B^T\mathbf{y}.$$

That is, if only k of the singular values are positive $[\text{rank}(X) = k]$, then the last $(n - k)$ components of $\mathbf{w}$ are not restricted by (20) or (21) and may take arbitrary values. Setting them to zero yields the minimum length solution. Here it is now obvious that the principal components enter with weights which are the reciprocals of their respective sizes, i.e., singular values. The jth column of U, which will be labeled $\mathbf{u}_j$, can be thought of as defining the direction of principal component j. The inner product $\mathbf{u}_j^T\mathbf{y}$ determines the projection of $\mathbf{y}$ in the direction $\mathbf{u}_j$, which, weighted by the inverse of the singular value S_{jj}, gives a contribution

$$(23) \qquad w_j = (\mathbf{u}_j^T\mathbf{y})/S_{jj}$$

from the jth column of B, i.e., the jth principal component. When (19) is used to transform the solution into terms involving the original variables

$$(24) \qquad \beta = V\mathbf{w},$$

large elements in $\mathbf{w}$ may dominate smaller ones, giving a least squares solution β which has an entirely unexpected appearance from the point of view of signs and values.

The residual sum of squares is

$$(25) \qquad Z = \mathbf{y}^T\mathbf{y} - \mathbf{y}^TB\mathbf{w} = \mathbf{y}^T\mathbf{y} - \mathbf{y}^TX\beta.$$

But substitution of (22) in (25) gives

$$(26) \qquad Z = \mathbf{y}^T\mathbf{y} - \mathbf{y}^TUSS^+U^T\mathbf{y}.$$

The matrix S is ordered, so that if the last $(n - k)$ singular values are zero, then

$$(27) \qquad Z = \mathbf{y}^T\mathbf{y} - \sum_{j=1}^{k} (\mathbf{u}_j^T\mathbf{y})^2,$$

that is, only the nonzero (non-null) components are included. Moreover, each component included reduces the sum of squares by $(\mathbf{u}_j^T\mathbf{y})^2$, once again underlining the central role of these products. Note, however, that the singular value does not appear in this expression. Thus, if component j having a relatively small singular value S_{jj} has only a minimal effect in reducing the residual sum of squares, it may nevertheless introduce a large w_j, hence large elements in β, if the ratio of $(\mathbf{u}_j^T\mathbf{y})$ to S_{jj} is large. A principal component of this type could be dropped from the regression with very little effect on the fit but a very large alteration in the solution β, though such regression solutions may be of limited utility in econometric applications because of their statistical properties. Mittelhammer and Baritelle and Fomby and Hill discuss estimators formed by dropping components corresponding to small singular values. The reader is cautioned that the former of these two papers uses the expression "principal components regression technique" to refer to the use of such estimates, while the subject of the present discussion is the mechanism by which least squares estimates are produced. Thus, the information contained in the quantities S_{jj} and $(\mathbf{u}_j^T\mathbf{y})$ remains useful for diagnosing the nature and severity of collinearities.

Practical Considerations

Given the development above, it is possible to suggest some of the information which a least squares

program using an svd can provide. First, the singular values themselves, when they vary greatly in magnitude, indicate the presence of collinearity. Furthermore, while correlation coefficients may indicate the parallelism of two variables, the singular values permit relationships in several dimensions to be recognized. Because the singular values are proportional to the scale of the numbers in the problem, a criterion used by the author for deciding that the predictor variable set is linearly dependent is

$$(28) \qquad S_{11} > 1000\, S_{nn}.$$

That is, the ratio of the largest to the smallest singular value exceeds 1,000, where the singular values are ordered as in (18). The factor of 1,000 is chosen from experience. While this factor has been quite appropriate for the author's own econometric applications, no doubt a much larger factor should be used when more precise data are involved, for instance in engineering.

An equivalent viewpoint of collinearity is provided by computation of the fraction of total variation in the independent (predictor) variables due to a given component. This is, for the ith principal component,

$$(29) \qquad f_i = S_{ii}^2 \Big/ \left(\sum_{j=1}^{n} S_{jj}^2 \right) = S_{ii}^2 \Big/ Tr(X^TX).$$

If any f_i is small, say less than 10^{-6} if the factor 1,000 is considered appropriate above, then the predictor variable set is essentially linearly dependent. Once again, the choice of the test value is at the discretion of the user. Note that the f_i are ordered if (18) holds.

Consider now that all variables are in deviation from mean form. Then $\mathbf{y}^T\mathbf{y}$ is the total sum of squares. The fraction of the total variation of the dependent variable $\mathbf{y}$ explained by the ith principal component is then

$$(30) \qquad E_i = (\mathbf{u}_i^T\mathbf{y})^2/\mathbf{y}^T\mathbf{y}.$$

The sum of the E_i over all the principal components gives the square of the coefficient of multiple correlation, that is, R^2. The ratio of E_i to R^2 gives the proportion of the explainable variation of y which is explained by principal component i. Note that equation (30) is still valid even if the data are not in deviation from mean form, but the interpretation using R^2 is now less meaningful.

The quantities f_i and E_i provide a tool for deciding whether or not a given regression relationship suffers from multicollinearity and if so, then the extent to which this collinearity causes instability in the computed regression coefficients. That is, the presence of a small value f_i indicates collinearity. However, if the same component also gives a small value E_i, then the component contributes to neither the variation in the predictor set nor to explaining the dependent variable $\mathbf{y}$. Such components could be dropped from the regression. While this is easily accomplished in practice by changing the definition (12) to read

$$(31) \qquad \begin{aligned} S_{ii}^+ &= 1/S_{ii} \quad \text{for} \quad S_{ii} > q \\ &= 0 \qquad\quad \text{for} \quad S_{ii} \le q, \end{aligned}$$

where q is a tolerance supplied by the user, possibly interactively, one must be aware that the estimates which result have statistical properties different from ordinary least squares (Fomby and Hill). It is important to remember that results obtained by such a procedure are conditional on the assumption that the linear dependence actually exists. Deleting components is not therefore recommended as a routine procedure for general application.

When f_i is small but E_i is large, principal component i will contribute very largely to the regression coefficients. These coefficients unfortunately will be poorly determined because a linear combination of the predictor variables which accounts for very little of the variation in that data is being asked to describe much of the variation in $\mathbf{y}$. Small perturbations in the data will therefore give large changes in the regression coefficients. In this case component i is needed to explain $\mathbf{y}$, but the true linear combination of the predictor variables which go to make up this principal component can only be fixed if more information is found.

Finally, when f_i is large and E_i is small for all components, there is simply very little relationship between $\mathbf{y}$ and the predictor variables. Once again we are forced to find more information.

The cost of computing least squares solutions by means of a singular value decomposition as compared to a conventional method employing the normal equations depends on the algorithms used as well as their implementation. The author's own experience suggests that the svd requires three to five times as much computing effort as the formation and solution of the normal equations. This must be balanced against the costs both human and machine of rerunning conventional calculations to discover numerical instability as in suggestion (c) of Boehm, Menkhaus, and Penn.

Examples

The Wampler problems (1) and (2) were solved on a Data General NOVA minicomputer operating in 23 bit binary floating point arithmetic using the singular value decomposition algorithm described by Nash (1975). The method of Nash and Lefkovitch gives similar results, though the nature of the problems is such that the output of the programs need not be identical. This is especially true when the system, as in the present case, cannot represent the data exactly due to the limited precision of its operation. Table 1 gives a comparison of results obtained by three programs: (a) ENHSVA—the svd of Nash (1975), also given as algorithm 2 of Nash (1979); (b) ENHNLR—the method of Nash and Lefkovitch, also given as algorithm 4 of Nash (1979); (c) ENHCRR—regression by solution of the normal equations. In this program all data are in deviation from means form. The X^TX matrix is inverted by the algorithm of Bauer and Reinsch

(Nash 1979, algorithm 9). Note that the order in which variables are presented to the regression program has an effect on the coefficients as Boehm, Menkhaus, and Penn have remarked.

In contrast to the dependence of the regression coefficients on ordering exhibited by the normal equation solver ENHCRR, the singular values computed by ENHSVA are insensitive to such ordering. For instance, with the ordering 1, 2, 3, 4, 5, 0 for the variables, where 0 represents the constant, the singular values are computed as 4.92276E+6, 26458.3, 409.891, 15.8218, 1.99291, and 0.769307, and the coefficients, assuming full rank, as β = (0.905485, 0.884127, 0.838069, 1.04047, 0.997045, 1.00007)^T. Likewise, entering variables in the order 5, 4, 3, 2, 1, 0, into ENHNLR gives computed singular values

$$4.92276E+6,\ 26458.2,\ 409.892,\ 15.822,\ 1.99292,\ 0.769314,$$

and coefficients

$$\beta = (1.01441,\ 0.960911,\ 1.01602,\ 0.997811,\ 1.00011,\ 0.99997)^T.$$

If one is interested in simply performing ordinary least squares regression calculations, the following observations can be made.

(*a*) The normal equation method ENHCRR computes the least accurate regression coefficients, as may be expected from an analysis such as that of Stewart (pp. 225–30) which shows that the condition of the least squares problem is worsened in the formation of the normal equations. Furthermore, while correlation coefficients and standard errors of regression coefficients do in the present case provide a warning that the least squares solution is unstable, there is no measure of the "nearness" to collinearity of the polynomial data.

(*b*) The singular values computed using different methods and different variable orderings are essentially identical. Similar results were obtained on a Univac 1108 using the algorithm of Golub and Reinsch. From the large difference in magnitude between the largest and smallest singular values, it is reasonable to expect that the regression coefficients will be very sensitive to small perturbations in the data as well as to rounding errors during calculation. Nevertheless, the coefficients computed by svd techniques are much closer to the exact coefficients than those found via the normal equations. Moreover, the variations observed due to choice of algorithm or variable ordering are much smaller.

(*c*) The svd methods allow principal components regression calculation. In table 2, we see that component 1 accounts for nearly 100% of the variation in the variable y for Problem (1). Using program ENHNLR, regression on this one component gave the solution:

$$\beta = (5.3801E\text{-}7,\ 9.44152E\text{-}6,\ 1.69112E\text{-}4,\ 3.07656E\text{-}3,\ 5.66593E\text{-}2,\ 1.0538)^T,$$

with a residual sum of squares 8.04017E+8 but an R^2 of 0.999757. The same principal component explains approximately 98% of the variation of the dependent variable of Problem (2).

An additional point should be made concerning the programs used to prepare these examples: all three programs have been written for small machines, that is, those having less than 6,000 characters of memory. As such programs have short code lengths, they are relatively easy to implement and maintain, even in a large machine environment.

Table 2. Singular Values, Fractional Variation, Fractional Explanation

Program	ENHSVA (5,4,3,2,1,0)				ENHNLR (1,2,3,4,5,0)	
	S_{ii}	$\mathbf{u}_i^T\mathbf{y}$	f_i	E_i	S_{ii}	$\mathbf{u}_i^T\mathbf{y}$
Problem (1)						
Component						
1	4.92276E+6	5.19513E+6	0.999971	0.99997	4.92276E+6	5.19512E+6
2	26458.2	28351.5	2.88863E-5	2.97815E-5	26458.2	−28351.6
3	409.891	453	6.93278E-9	7.6031E-9	409.895	453.299
4	15.8218	18.5	1.03296E-11	1.26805E-11	15.8216	−18.5794
5	1.99291	2	1.63887E-13	1.48202E-13	1.99293	2.08093
6	0.769308	0	2.44214E-14	0	0.769315	8.88185E-2
Problem (2)						
Component						
1	As	104.74	As	0.980296	As	104.74
2	for	13.777	for	1.69608E-2	for	−13.777
3	problem	4.67591	problem	1.95374E-3	problem	4.67592
4	1	2.44931	1	5.36073E-4	1	−2.44929
5		1.62742		2.36666E-4		1.62743
6		0.434611		1.68786E-5		0.434627

Conclusions

The singular value decomposition methods presented above are no longer a novelty in the computational world, but neither are they in widespread use in least squares regression programs. However, packaged programs are beginning to incorporate such techniques, and individual users are starting to employ programs such as those given by Lawson and Hanson. The gap, which this paper has tried to fill, lies in the appreciation of the utility of the intermediate output of an svd in identifying and coping with collinearity. The exercises proposed by Boehm are tedious and unnecessary when good methods exist for discovering instability in regression coefficients. Worse, their proposals offer no certainty that a problem has disclosed its pathological nature. While to some extent economists and others must live with other people's programs, they can and should be asking that these programs, as tools, be sharp and durable.

[Received May 1977; revision accepted January 1979.]

References

Bauer, F. L., and C. Reinsch. "Inversion of Positive Definite Matrices by the Gauss-Jordan Method." *Linear Algebra*, ed. J. H. Wilkinson and C. Reinsch, pp. 45–49. Handbook for Automatic Computation, vol. 2. Berlin: Springer, 1971.

Beaton, A. E., D. B. Rubin, and J. L. Barone. "The Acceptability of Regression Solutions, Another Look at Computational Accuracy." *J. Amer. Statist. Assoc.* 71(1976):158–68.

Boehm, W. T., P. J. Menkhaus, and J. B. Penn. "Accuracy of Least Squares Computer Programs: Another Reminder." *Amer. J. Agr. Econ.* 58(1976):757–60.

Fomby, T. B., and R. C. Hill. "Deletion Criteria for Principal Components Regression Analysis." *Amer. J. Agr. Econ.* 60(1978):524–27.

Golub, G. H., and C. Reinsch. "Singular Value Decomposition and Least Squares Solutions." *Linear Algebra*, ed. J. H. Wilkinson and C. Reinsch. Handbook for Automatic Computation, vol. 2. Berlin: Springer, 1971; *Numer. Math.* 14(1970):403–20.

Grossman, S. I., and G. P. H. Styan. "Optimality Properties of Theil's BLUS Residuals." *J. Amer. Statist. Assoc.* 67(1972):672–73.

Lawson, C., and R. J. Hanson. *Solving Least Squares Problems*. Englewood Cliffs, N.J.: Prentice-Hall, 1974.

Longley, J. W. "An Appraisal of Least Squares Programs for the Electronic Computer from the Point of View of the User." *J. Amer. Statist. Assoc.* 62(1967):819–41.

Mittelhammer, R. C., and J. L. Baritelle. "On Two Strategies for Choosing Principal Components in Regression Analysis." *Amer. J. Agr. Econ.* 59(1977):336–43.

Mullet, G. M., and T. W. Murray. "A New Method for Examining Rounding Error in Least Squares Regression Computer Programs." *J. Amer. Statist. Assoc.* 66(1971):496–98.

Nash, J. C. *Compact Numerical Methods for Computers: Linear Algebra and Function Minimisation*. Bristol: Adam Hilger; New York: Wiley-Halstead, 1979.

———. "A One-Sided Transformation Method for the Singular Value Decomposition and Algebraic Eigenproblem." *Computer J.* 18(1975):74–76.

———. "Problèmes Mathématiques Soulevés par les Modèles Economiques." Paper presented at le 9e Colloque des Mathématiciens du Québec, Ottawa, March 1978.

———. "Some Methods for Solving Single Equation Linear Least Squares Regression Problems," reprinted with revisions. Economics Branch, Agriculture Canada, Ottawa, June 1974.

Nash, J. C., and L. P. Lefkovitch. "Principal Components and Regression by Singular Value Decomposition on a Small Computer." *Applied Statistics* 25(1976):210–16.

Rao, C. R., and S. K. Mitra. *The Generalized Inverse of Matrices and Its Applications*. New York: John Wiley & Sons, 1971.

Stewart, G. W. *Introduction to Matrix Computations*. New York: Academic Press, 1973.

Wampler, R. H. "A Report on the Accuracy of Some Widely Used Least Squares Computer Programs." *J. Amer. Statist. Assoc.* 65(1970):549–65.

Webster, J. T., R. F. Gunst, and R. L. Mason. "Latent Root Regression Analysis." *Technometrics* 16 (1974):513–22.

Books Reviewed

Breimyer, Harold F. ***Farm Policy: 13 Essays.*** **Ames: Iowa State University Press, 1977, vii + 121 pp., $7.50.**

These essays are directed toward an understanding of the philosophical foundations and value structures of American farm policy. They are discursive and retrospective, generally not a tract of advocacy, or a prescription for policy. For the most part, they do not analyze policy alternatives. They are, in Breimyer's words, intended to prick, stimulate, and stir imaginations; above all, to teach. In this objective, they succeed exceedingly well.

Breimyer begins by alluding to the paradoxes of farm policy. These include the drive for individual freedom and the attraction of combining to get the benefits of political power; the distinction between the material content of farm policy and the social organization of agriculture; the differences between crop and animal agriculture; and, finally, almost as a general theme, the contrast between the ancient agrarian root of farming and the industrial aspects now superimposed upon it.

According to Breimyer, these paradoxes give farm policy a mixed, ambiguous, agrarian and industrial content. Agrarian policies give rise to various programs to stabilize supply and raise price. The industrial orientation, however, is poised toward the imperious marketing system and its mechanism for influencing resource supply and demand, and the prices of farm products. Thus, on the one hand, the agrarian tradition gives credence to the family farm as a fundamental tenet of policy. But, most policies supported by farm organizations and generally adopted actually favor more and more industrialization of farming to the disadvantage of family farms. This is not accidental. The family farmer generally supports the industrial-type policies, but, in so doing, leads to what Breimyer calls the farmer's noninstinct for self preservation.

Examples of this noninstinct are widely dispersed, and Breimyer mentions most of them. There are the general policies of open competition for land and support for tax and credit policies that heighten this competition, often to the relative disadvantage of the family farm. The general tax laws give some important advantages to farm corporations, often especially the larger corporations. The liberal provisions for reporting important categories of farm income as capital gain favor the tax payer in high brackets. Cattle ranching is an especially attractive tax haven. The so-called reforms affecting taxation of farm inheritances and estates tend to favor the industrial-type operation. The opposition of the family farmer to effective labor unions for hired farm workers penalizes the family farmer relative to the larger-than-family farm operation. The failure of government to enforce the 160-acre limitation in sale of water from federally funded irrigation projects provides an important subsidy to the large irrigated farm. Farmers' cooperatives, theoretically at least under the policy direction of farmers, generally fail to provide competitive advantages to the family farm.

These basic paradoxes, which run as a continuing thread through Breimyer's essays, are importantly a product of the classic textbook fallacy of composition. The family farmer's noninstinct for self-preservation can be traced to the assumption that what is good for the individual family's farm is good for family farms as a whole. Thus, individual family farmers fight to retain the modest benefit they may gain from the capital gains tax, even though this hands a much larger windfall to the larger-than-family farm that competes for the same resources. Breimyer argues that the family farm will not necessarily survive just because of its technical efficiency; and farmers are chided on their divisiveness on income and estate tax rules, land use controls, pollution control, and foreign trade.

Breimyer generally avoids specific policy solutions except in certain cases, such as the use of programmed grain reserves to assure an export capability, more aids for resource adjustment, direct payments, and the like. But the general meaning is clear. The essays are succinct and, in some cases, terse. Overall, although some may question the benefits to be obtained in attempting to preserve the agrarian values that Breimyer sees slipping away, the essays make clear that important changes are required in current policy if these values are to be preserved. The essays do prick, stimulate, and stir imagination, and provide a general theme for teaching farm policy. The essays will be useful for collateral readings in farm policy, for the classroom, extension programs, and other occasions.

Harold G. Halcrow
University of Illinois at Urbana-Champaign

Doll, John P., and Frank Orazem. ***Production Economics, Theory with Applications.*** **Columbus, Ohio: Grid, 1978, x + 406 pp., $20.95.**

This book was written to be used as an undergraduate production economics text for students whose economics training includes only a principles of agricultural economics course. The book essentially can be divided into two parts. The first five chapters and chapter 7 develop the traditional neoclassical theory of production and distribution under perfect competition. The remainder of the book consists of discussions of production decision mak-

ing when one or more of the assumptions of neoclassical theory are relaxed. It contains chapters that address production decisions through time, production decisions under risk and uncertainty, the use of linear programming as a tool in decision making, and a historical perspective of farm adjustments in the United States.

In the preface, the authors allude to goals of merging abstract economic theory and applications of the theory to real situations in agriculture and maintaining flexibility so that the book can be used by students with a knowledge of differential calculus as well as those with mathematical training only in geometry and algebra. Doll and Orazem succeed in both goals. A thorough treatment of production theory is amplified by numerous production problems and applications. The authors also do an excellent job of presenting the material, such that those sections on calculus can be omitted without loss of continuity. They are not apologetic for the inclusion of calculus, and it is integrated throughout the text in theory, applications, and exercises.

The treatment of the neoclassical theory of production and distribution under perfect competition is well done. Tables, graphs, and calculus are merged such that the examples are explicit and easily understood. A good discussion of some often ignored topics (e.g., lumpy inputs, corner solutions, discontinuous production functions, linear isoquants, and constrained versus unconstrained optima) also is included. The authors begin their discussion of production functions with a simple approach assuming one input and one output and then address increasingly more complex production functions including the multiple input/multiple output case.

The chapter that addresses temporal production decisions contains a number of decision criteria for profit maximization and durable input acquisition over time. Most undergraduate students will likely have considerable difficulty choosing the appropriate criterion because this choice often hinges on a fairly subtle point. However, this problem can largely be overcome by meticulous, explicit instructor presentations.

The decision theory (under risk and uncertainty) chapter is somewhat superficial. The Frank Knight risk-uncertainty dichotomy is of little practical use, and could be played down considerably. It is somewhat unfortunate that the authors chose not to address alternative objective functions of decision makers, because the assumption of expected profit maximization is somewhat unrealistic. The treatment of game theory should either be expanded to include more than one decision criterion or it should be omitted.

More emphasis in the linear programming chapter could be given profitably to applications and examples and setting up production problems in an LP framework. The authors' discussions of the dual and the simplex procedure are somewhat detailed for a book of this type (and, in fact, employ 50% of the chapter).

Doll and Orazem have done a commendable job on their text. The presentation is economically and mathematically sound and contains a minimum of "first edition" errors and omissions. However, those instructors planning to go beyond the neoclassical theory will need to provide some supplementation of readings.

James K. Whittaker
Oregon State University

Friedrick, Robert A. *Energy Conservation for American Agriculture*. Cambridge, Mass.: Ballinger Publishing Co., 1978, xiv + 173 pp., price unknown.

This book is one of a series of eight prepared by the Environmental Law Institute State and Local Energy Conservation project. Its primary purpose is to evaluate strategies that states might use to reduce energy consumption in agricultural production.

The book contains six chapters. Chapter 1 briefly reviews energy use in agriculture, reasons for energy conservation, and obstacles to energy conservation. Chapter 2 sets forth four broad categories of policy options that might be used by states to reduce energy use in agriculture: financial incentives, taxes, regulations, and information transfer programs. Advantages and disadvantages of each option are discussed at some length but there is no rigorous economic analysis. Chapters 3 and 4 discuss the potential for reducing direct and indirect uses of energy on farms in the broad categories of machinery operations, irrigation, crop drying, specialized operations (fruit, vegetables, and greenhouses), fertilizers, and pesticides. Chapter 5 covers meat, dairy, and poultry production. It points out that, in general, livestock is a net energy loser and discusses some options for change. These three chapters have similar formats. For each category of energy use, some or all of the policy options presented in chapter 2 are suggested as means of achieving reduction in energy use. The final chapter explores the potential for reduced energy use by increased urban gardening and the policy options for encouraging it.

The book draws heavily on the recent literature on energy use in agriculture and potentials for decreased use. Each chapter has extensive footnotes, including references to items such as USDA publications, CAST reports, and proposed or enacted state laws relative to energy conservation.

The author points out that energy use in agricultural production, while large, accounts for a small percentage of the total U.S. energy use. Direct and indirect energy use in agriculture are estimated to be 3% to 4% and 1% to 2%, respectively, of the U.S. total. The author concludes that there is potential for saving appreciable amounts of energy in the agricultural production sector. He also recog-

nizes that some of this potential may be difficult to achieve because there is insufficient incentive to save energy and, in many situations, plenty of incentive to use energy in agricultural production.

Most agricultural economists will find the book neither exciting nor one which contains rigorous economic analysis. Those who have studied energy use in agriculture will find little that is new. Many will find some errors, omissions, and misconceptions. However, the greatest disappointment will be that the approach is more from a legal than from an economic viewpoint. Economic issues related to the four policy options are treated in a very cursory manner. Discussion of the advantages and disadvantages of various policies, while reasonable, includes limited economic analysis.

One example of an apparent misconception is in the livestock chapter. It correctly points out that livestock use more energy than they produce but, in the case of ruminants, convert feed that humans would not eat. However, some of the suggestions about increased grassland and reduced feedlot production of cattle are based on faulty reasoning. There is an implication that large amounts of rangelands are currently unused or underutilized. While this could be true at the current stage of the cattle cycle, it is not a general phenomenon.

The discussion of information transfer suggests that there is a large amount of information available on energy conservation that is not being effectively communicated to farmers. There is also a suggestion that farmers are not adopting energy-saving technology because they are not being fed enough information on the economics of investing in energy-saving devices. The author does not seem to recognize that the economics of some proposed energy-saving technology is unfavorable to the farmer.

On the positive side, it is likely that persons in state governments who are unfamiliar with energy use in agriculture would find this book quite useful as an overview of energy use in agricultural production, possible areas for conservation, and options of states for encouraging conservation. Despite its shortcomings, I believe that most agricultural economists would agree that for a book produced by an attorney rather than by an economist, the result is quite reasonable.

George L. Casler
Cornell University

Goldschmidt, Walter. ***As You Sow: Three Studies in the Social Consequences of Agribusiness.*** **Montclair, N.J.: Allanheld, Osmun & Co., 1978, 505 pp., $16.50.**

Drache, Hiram M. ***Tomorrow's Harvest: Thoughts and Opinions of Successful Farmers.*** **Danville, Ill.: Interstate Publishers, 1978, 314 pp., price unknown.**

Goldschmidt's lengthy book is divided into three parts. Part I, called "As You Sow," discusses the social consequences of industrialized (or corporate) farming in the town of Wasco, located in California's Central Valley. It is based on eight months of observation and field research starting in the fall of 1940, and was originally published in 1947 by Free Press. Part II, "Agribusiness and the Rural Community," is a comparative analysis of rural life in two neighboring towns, Arvin and Dinuba. This work, based on one month of field research in each town during the spring of 1944, is intended to provide a means of checking conclusions reached in Wasco. It was published as a committee print by the Senate Small Business Committee in 1946. Part III, "Agribusiness and Political Power," which appears for the first time in the new book, is an historical account of efforts to suppress Goldschmidt's research on the social effects of industrialized farming. The book has a 30-page introduction in which the author maintains that corporate control over farm production is expanding, helped by public policies. He sees the net outcome for society as a loss of personal independence, together with a decline in traditionally valued qualities such as egalitarianism and hard work.

According to Goldschmidt, the transformation of Wasco from a traditional farming community to a center of industrialized farming had its roots in land policy, irrigation technology, farm mechanization, crop specialization, an impoverished and impersonal labor supply, and large-scale operations. As the industrialization process proceeds, farmers have increasing contact with suppliers and marketing agents, while the rural community itself becomes more dependent upon outside corporations, big-city banks, and state and federal agencies. In this manner, urban values follow technology and mechanization into the rural community. Once urban values are introduced, they create additional pressures for more industrialization. Individuals adopt specialized functions (including a separation between labor and management), large-scale farming becomes dominant, the number of persons independently employed declines, the community comes to be composed overwhelmingly of laborers, and two social classes emerge. In short, the author believes that the rural equivalent of urban society is created.

Goldschmidt anticipates that urbanized rural society will substitute a system of social values based on occupational and pecuniary standards for the social unity, homogeneity, and personal values that characterize rural communities. To illustrate the point he describes the community of Wasco in terms of two social classes: an upper class of businessmen, farmers, and professionals; and a lower class of mostly agricultural laborers. He presents evidence from many aspects of life in Wasco to demonstrate a marked lack of social contact between the two classes including the exclusion of farm laborers from participation in community decisions, segregation in recreation and religious life, and poor housing and other urban slum conditions.

In Arvin (located near Bakersfield) and Dinuba (located near Fresno), Goldschmidt found evidence to support his thesis that industrialized farming leads to urbanization of rural communities. The two communities, selected because of their many similarities, differ in one important aspect: Arvin, surrounded by corporate-owned and other large-scale farming operations, is "a large farm community," while Dinuba, with many moderate- or family-sized farms, is a "small farm community." Thus, Arvin and Dinuba provide the basis for a controlled comparison of the effects of farm size on the character and quality of rural community life.

On the basis of personal interviews and other data collected in the two communities, Goldschmidt concludes that Dinuba is a superior place to live; it "fulfills rather well our normal expectations of social life." Arvin provides fewer opportunities for self-employment, lower standards of housing and public services, fewer nonfarm businesses, a lower volume of retail trade, less community loyalty, and a much greater degree of social segregation. Indeed, there are significant differences between the two communities.

The final section of the book describes the controversy surrounding the study of Arvin and Dinuba, and efforts to suppress publication of the research. It is not surprising that field research involving questions on housing conditions, standards of living, and social and religious participation should come under critical scrutiny. But in this case, the attack was systematically conducted by the representatives of corporations and other owners of large amounts of farmland, in a manner apparently common to California water politics. The ability of a few powerful interests to alter the course of publicly supported research certainly lends credibility to the author's view of it as a small part of a much broader effort to subvert the intent of Reclamation policy.

Yet, Goldschmidt's analysis has many shortcomings. Most of these relate to the weaknesses of the case study approach, and the difficulties of establishing causal links among many interrelated variables. Are the social differences between Arvin and Dinuba really the result of large-scale farming? Or do they perhaps stem from a combination of other factors—such as sources of water, types of crops, dates of settlement, and goals of community leaders? And are the findings perhaps unique to irrigated farming and rural life in California? The author does not always succeed in separating conceptual reasoning and objective description from personal bias and nostalgia for community life. Moreover, he does not fully explore the potential benefits of industrialized farming. It is likely that mechanization has reduced the drudgery of farm work, provided farm people with additional time to pursue community activities, and, in some cases, even eliminated the need for a separate class of agricultural laborers.

Tomorrow's Harvest, by Hiram Drache, is an extensive description of what a group of progressive, innovative farmers and their wives think of the business of farming and its future. In sum, the book is a pitch for large-scale, technologically modern, family-oriented farms and a stiff warning against public policies restricting farm size. Drache's analysis is based on personal interviews with more than 200 farm families in the Upper Midwest, Southern Canada, and Europe. Written in anecdotal style, the book is structured around a series of chapters that present the opinions of farm people on a variety of subjects: world food supply; farm size and growth; the management of farm labor; buying and selling practices; farm organizations and public policy; and European agriculture.

Drache emphasizes that it is the collective view of those interviewed and his own personal opinion, that the goal of agriculture should be to provide an abundant supply of food to consumers at the lowest possible cost and, at the same time, to achieve adequate returns to farmers who use the best available technology and business practices.

The trend toward fewer, larger, and more capital-intensive farms is viewed as a natural consequence of technological innovation and as synonymous with greater economic efficiency. Society's most pressing problems include finding ways to reduce the time lag between the invention of a new technology and its widespread adoption, and making sure that financial institutions keep up with the rising capital needs of modern farming.

Drache's interviews lead him to conclude that family farming has an edge over corporate-controlled agriculture. Two noneconomic factors—personal motivation and the choice of the right spouse—are primary determinants of success. Large corporations cannot provide sufficient incentives to compete with highly motivated farm families, and they definitely cannot "tighten the belt" and live with a very limited cash flow.

This book will prove interesting reading to those wanting to know more about the personal attributes and business strategies of a select group of farm people who have succeeded in adopting new technologies and management practices resulting in remarkable growth of farm size. Readers with other notions of success will be disappointed. It seems likely that Drache overstates the benefits to consumers of large-scale farming, because most of the farms considered are much larger than the minimum size necessary to capture known economies of scale. Economic efficiency is defined in the narrow sense, without regard for negative effects such as externalities, concentration of ownership, and socioeconomic consequences for rural communities. Drache's book supports the notion that knowledge of human behavior is essential to understanding the behavior of the firm. Beyond that, it is generally a gee-whiz story about four-wheel drive tractors and superfarms.

Goldschmidt and Drache both have a lot to say about changes in farming, personal values, and cul-

tural patterns. Both authors agree that family farming can reap most of the benefits of specialization, bigness, and modern technology without forcing society to sacrifice traditional goals such as individual initiative, freedom, and democracy. A major difference is that Goldschmidt argues for policies favoring moderate-sized farms, with government intervention to prevent land monopolies and to facilitate entry into farming. Drache, on the other hand, argues for a smaller number of large farms and against government intervention which he sees as tending to impede the expansion of family enterprises.

Peter M. Emerson and James G. Vertrees
Congressional Budget Office

Hagman, Donald G., and Dean J. Misczynski, eds. *Windfalls for Wipeouts: Land Value Capture and Compensation.* Chicago: American Society of Planning Officials, 1978, xliv + 660 pp., $23.95.

Actions by local, regional, state, and federal governments that directly or indirectly affect land use cause gains and losses for real estate owners. With the increasing occurrences of growth controls and other environmental regulations, the severity and number of these effects can be expected also to increase, perhaps dramatically. This book concerns those gains and losses, termed windfalls and wipeouts, respectively. Contributors include the editors, who are also the primary co-authors, Frank Schnidman, Urban Land Institute Research Counsel, and seven UCLA law, planning, and economics graduate students who worked on this ambitious HUD-sponsored project.

The book is organized into six major sections. The first introduces the concepts of windfalls and wipeouts. Recommendations on how to design and implement two windfalls for wipeouts (WFW) systems, one an omnibus proposal and the other an incremental step, follow in the second section. Economic aspects are discussed in the third section, including the theoretical occurrences of windfalls and wipeouts, the probable incidences of windfall recapture and wipeout compensation, and potential efficiency and equity effects of a WFW system. The fourth section considers four approaches to compensate wipeouts (e.g., inverse condemnation), while section five discusses nine techniques for recapturing windfalls (e.g., special assessments). The final section then turns to techniques that have been used or proposed to recapture simultaneously windfalls and compensate wipeouts (e.g., transferable development rights). Comprehensive reviews of windfall recapture and wipeout compensation in Canada, Australia, New Zealand, England, and the U.S. (collectively referred to as CANZEUS) are contained in the last three sections.

Although not stated explicitly, the book seems to have twin purposes. The first is to build a rationale for a WFW system. This is consistent with the following premise that opens the book:

> We believe that windfalls and wipeouts lead to inequities that impair the ability of both the private and public sector to achieve desirable patterns of land use. These inequities would be reduced if the public "taxed" some windfalls in order to compensate some wipeouts, which, in turn, would lead to more desirable land-use patterns (p. 1).

"Desirable" land-use patterns are not defined in the context quoted but one suspects that efficiency, equity, and other planning criteria are involved. The prescription to institute WFW systems is predominantly based on the hypothesis that requiring at least partial wipeout compensation and windfall recapture will cause public decision makers to be more aware of all costs and benefits from their actions that affect land use, and thereby increase the efficiency of land planning. However, the analysis by Misczynski (chap. 7), concludes that it is unclear whether a WFW system will increase or decrease efficiency. The equity analysis concludes that WFW policies will reduce planning impact inequities among real estate owners (i.e., promote horizontal equity), but will probably not alter the vertical income distribution pattern. The reader is left to ponder the apparent lack of strong support by the efficiency and equity analyses for the prescription. The strongest argument may be that unmitigated wipeouts and unrecaptured windfalls create strong incentives to break well-designed land use plans (chap. 3).

The second purpose is to provide a comprehensive reference on wipeout mitigation and windfall recapture techniques. The primary intended audience is land economists, planners, and lawyers, but other academic disciplines and real estate-associated occupations should also benefit. Chapters 8–23 are the most comprehensive reviews of wipeout mitigation, windfall recapture, and windfall for wipeout techniques in CANZEUS. These chapters are excellent summaries of administrative and legal histories, and analyses of strengths and weaknesses; they should be required reading for those currently conducting or contemplating research in this area. The methodology is one of planning and economics liberally dosed with legal analysis.

Based upon the study's analyses, the authors recommend two alternative WFW systems. In large part, they are modeled on the WFW system termed zoning by special assessment-financed eminent domain (chap. 22). The most critical technical problem with either alternative is to accurately identify and measure the publicly induced changes in land or real estate values. If a WFW system is to provide the correct incentives to effectuate "desirable" land-use patterns, then a reliable, and probably inexpensive, mechanism must be found. The property tax assessment system is proposed for this role. To propose otherwise would mean a substantial increase in administrative costs and negate any

chance of seriously considering a WFW system in the current government fiscal climate. Recognizing the nasty theoretical measurement problems, the authors argue that the pressure placed on the property tax assessment system by a WFW policy would serve to upgrade the quality of assessments. One could alternatively argue that given the significant stakes involved in many windfall and wipeout cases, the WFW system might be the straw that breaks many property tax assessors' backs.

The editors conclude that adoption of a WFW system in the United States is problematical—an observation consistent with this reviewer's feeling that those who perceive potential losses under a WFW system are more numerous and politically stronger than those expecting gains (compensation). This pessimistic conclusion should not, however, deter potential readers from this very useful addition to the land-use planning and control literature.

Dave Ervin
University of Missouri

Pimentel, David, ed. *World Food, Pest Losses, and the Environment.* Boulder, Colo.: Westview Press, 1978, xxv + 206 pp., $16.50.

A hazard of today's largely discipline-oriented research in agriculture is that perspective is often lost. Such specialists as pathologists, entomologists, and ecologists tend to view the world as having finite quantities of natural resources that can produce some maximum quantity of food. Any losses from pest attacks subtract from this total food stock and ought not to be tolerated in a civilized, humane society. Economists recognize the role of price ratios in the substitution among resources used and quantities of commodities produced as well as the role of new technology in producing greater food stocks from a given quantity of natural resources. Economists, however, in their zeal to examine increased efficiencies in production, generally underestimate the magnitude of pest losses—the authors' "bottom line" is that "pest populations are consuming and/or destroying nearly ½ of the world's food supply" (p. 13)—and the tremendous research input normally required to maintain current levels of output and production efficiency. (In Canada, about 40% of all publicly funded research in agriculture is protection-oriented—weeds, insects, and diseases.)

The papers included in this book were presented at a symposium of the American Association for the Advancement of Science meeting in Denver, Colorado, in February 1977. The objective of the symposium was to examine current food shortages and the role that pests play in reducing world food supplies. Papers were presented on all major types of pest losses—insect, disease, and weed losses in crops; post-harvesting losses in storage, processing, and transportation; and animal losses from parasites. Environmental aspects of pest control were discussed in one paper. The book is completed by two papers of a more specific nature: one describing pest problems in the production of millet in Mali, the other justifying research on post-harvest losses as a priority of the new United Nations University.

The papers offer excellent reviews of the literature on pest losses. Though probably not comprehensive with respect to any particular pest, the discussion illustrates a thorough knowledge of the subject assigned to each author. Most papers include a long list of references. This book ought to be read by agricultural economists who are concerned with food production problems on a global scale, even though it offers few insights into economics of pest management problems. Though written by recognized authorities on pest problems, these papers display an alarming lack of understanding of the economic principles that govern rational pest control procedures. Furthermore, the quality of loss assessment data upon which pest control decisions and recommendations are being made appears to be woefully inadequate. One author claimed that only nine references out of 200 surveyed in the area of post-harvest losses have somewhat thorough analyses of losses under field conditions.

It is difficult to understand why the agricultural economics profession has continued largely to ignore this very important area of research. It would appear that substantial payoffs could be realized from closer collaboration between pest researchers and agricultural economists. These would result from a better allocation of research resources, easing of information constraints in the transfer of technology, and policy alternatives to deal with externalities found in pest control programs.

References to economic concepts are found everywhere in the book—the notion of an economic threshold, integrated pest management schemes to optimize benefit-cost ratios, increased costs of production when pests are present, accurate assessment of losses, benefit-cost ratios for alternative research strategies, externalities in pesticide use, increased resistance to continued use of pesticides. However the authors, who were trained in biological sciences, seldom have the expertise required to deal adequately with these issues. They continue to estimate area or country-wide losses from an accounting viewpoint, i.e., they extend production losses from one animal or hectare across a region with no recognition that price changes normally accompany quantity changes. Pest researchers continue to assess losses from the point of maximum total product rather than from the economically optimal point of total product. These and other economic *faux-pas* can be forgiven easily until it is remembered that many decisions about funding research, extension, and pest control programs are taken on the basis of this type of information. Agricultural economists can learn something from this book—not about economics, but about something

far more relevant, the level at which our science is being used and understood by other prominent, professional agriculturists.

Kurt K. Klein
Agriculture Canada

Schultz, Theodore W., ed. ***Distortions of Agricultural Incentives.*** **Bloomington: Indiana University Press, 1978, viii + 343 p., $12.95.**

This book presents the papers given at a three-day workshop, Resources, Incentives and Agriculture in 1977, sponsored by the American Academy of Arts and Sciences and organized by T. W. Schultz. The main focus of the book is clearly expressed by the editor in the preface: "The biological constraints on food production have been substantially reduced by the advances in agricultural research and by the availability of additional capital. But it has become increasingly evident that the adoption of the research contributions and efficient allocation of the additional capital are being seriously thwarted by the distortion of agricultural incentives. For lack of optimum incentives it is not possible for farmers in many low-income countries to produce the potential supply of food" (vii).

Accordingly, three preliminary papers by T. W. Schultz, Sir Charles Pereira, and H. A. Steppler are designed to make the point that "although many scientific and technical problems remain to be solved, their scale is now minor in comparison with that of the 'social engineering' required" to overcome the political, social and economic constraints hampering the growth in food production (Pereira, p. 25). These constraints are due to the fact that governments undervalue agriculture and negatively distort the incentives faced by farmers. To speak of distortion, one must compare actuality with a reference. For Schultz "an *optimum* economic incentive provides the information that leads producers to allocate resources in ways that result in a maximum of production that will clear the market at the price that maximizes the utility of consumers" (p. 6).

In the core of the book, entitled "Distortions of Incentives," a series of papers by David Hopper, Gilbert Brown, Reed Hertford, Randolph Barker, and Martin Abel review the various types of government interventions which distort incentives and present analyses of the reasons why many governments do so. The rest of the book is devoted to discussions of related issues presented in papers on international markets (D. Gale Johnson), the organization of research (Robert Evenson), investments in human capital (Finis Welch), institutional innovations (Vernon Ruttan), and the quest for equity (Edward Schuh).

The list of contributors (papers' authors and those who commented on them) is very impressive: it includes professionals who are the most, or among the most, competent experts in the field. Accordingly all the papers reach a very high standard of professional excellence. In addition, the workshop must have been well prepared because the book avoids the usual trap of being only a collection of disparate essays. On the contrary, most papers are focused on the central problem. The few exceptions deserve attention because, in my opinion, it is the subject matter of these papers which, in the present state of knowledge, does not lend itself to be well related to the main theme of the book.

Coming back to the definition of optimum incentive given by T. W. Schultz, the reference to a dual optimization (maximum of production and maximum utility of consumers) raises a thorny theoretical question which I have not fully elucidated. Usually, optimization problems are formulated as searching for one optimum under a set of constraints (which *inter alia* may reflect other economic objectives). Actually, in their discussions the authors do not use this theoretical reference. In discussing prices they all use world market prices in spite of the general recognition that the functioning of international markets for agricultural products leaves much to be desired, resulting particularly in great price instability. The point is made by several contributors. D. Gale Johnson asserts, it is true; "Yet with all these defects, the international market prices of agricultural products come much closer to reflecting the true alternative costs of various commodities than do the managed domestic prices of many, if not most, developing countries" (p. 213). But the evidence supporting this statement is, and can only be, very limited. D. Gale Johnson is more convincing when he argues that, in many instances, developing countries could benefit much from a greater involvement in world trade. Sir John Crawford, however, points out that "entering world trade is not the simple decision that I think Gale Johnson implies in his paper" (p. 186). These few points should be sufficient to illustrate that, from both a theoretical and a practical standpoint, defining price distortion is never a clearcut operation.

Another open issue is that of appropriate technology. Both Sir Charles Pereira and Edward Schuh denounce the demands that science be used not only to increase agricultural productivity but also to correct the maldistribution of wealth in the poorer nations. Yet the very creation of the international agricultural research centers and their success illustrate that science can be used to correct a bias in the orientation of agricultural research. Tropical research, until then, was focused mainly on plantation crops, of interest to colonial powers, and very little on food crops, of particular interest to the poor. Besides, the induced innovation hypothesis, so eloquently presented by Ruttan and for which there exists substantial empirical support, implies that the agricultural research and extension system can and does respond to economic needs, particularly to changes in resource endowments.

The most serious limitation of the book is the inadequacy of our knowledge regarding how government policies are determined. If we accept, in

spite of the questions raised above, that agricultural incentives are indeed distorted against agriculture, the "positive economics" advocated by T. W. Schultz should deal with the question: why is it so? Here, we can only agree with Reed Hertford's statement: "We economists do not really have, as yet, a robust and thorough-going explanation of why agriculture is mistreated by the economic policies of developing countries" (p. 137). Similar points are made by several contributors. In his discussion of Schuh's paper, Castle rejects the idea that economists know the "best" policies and argues that our "behavioral theory for the public sector is not comparable to that which exists for the private sector" (p. 332). Similarly, Ruttan writes that it is desirable "that economists and other social scientists begin to develop greater depth in the positive analysis of the social and political forces bearing on the choice of economic policy" (p. 300). Incidentally, this lack of knowledge is probably responsible for the less-than-clear relationship between the main theme of the book and the otherwise interesting papers on research (Evenson), human capital (Welch), and institutional innovations (Ruttan). Our knowledge of the relationships between policies in these fields and incentives faced by farmers is quite vague. This leads me to make a plea for developing an analytical political economy in order to improve our understanding of the policy-making process. In doing so, economists should avoid the danger, so well pointed out by Schultz, i.e., only to rationalize what is being done by government, and thus "become 'Yes-men' in the halls of political economy" (p. 9).

Given our inadequate knowledge of the policy-making process, I could not help but be somewhat irritated by the complacent tone of some papers preaching the free market ideology. Fortunately, the book is much more balanced than suggested by these over-simplifications. All agricultural economists are strongly urged to read it because it deals with essential problems, and to read all of it because the issues are complex and deserve careful analysis, and because *Distortions* should invite us all to intellectual modesty.

Michel Petit
École Nationale Superieure
Des Sciences Agronomiques Appliquées
France

Shaffer, Harry G., ed. ***Soviet Agriculture: An Assessment of Its Contributions to Economic Development.*** **New York: Praeger Publishers, 1977, xvi + 166 pp., $18.95.**

"It is the purpose of this volume to expose the reader to the whole spectrum of views on Soviet agriculture," says the preface (vii). This indeed has been attained, as far as views and beliefs are concerned, less so with regard to a serious discussion of the facts.

The book opens with M. Gardner Clark's overview of Soviet agricultural performance and policy from collectivization to the mid-1970s. Concise and, at the same time, rather comprehensive as it is, the treatment of the subject is one of the best of this kind published in recent years and presents a rich array of information interspersed with critical comments. While most Sovietologist writings suffer from concentrating on Soviet sources and disregarding parallel Western research on the subject, Clark almost falls into the opposite extreme. His contribution further suggests that only by later additions was it brought up to the mid-1970s; essentially it was an earlier article ending at the beginning of the decade. This reviewer would take issue with some of the assessments of the reform of the labor remuneration system, of the economic rationality and success of the small-scale nonagricultural subsidiary enterprises on farms, and, most of all, with the presentation of the pros (no cons) of the unsupervised link system. On the latter subject, Gardner Clark does not differentiate between links of earlier years and on labor-intensive crops as distinct from comparable sub-units on a higher level of mechanization and for grain growing. The case in favor of the USSR becoming a permanent food importer on a large scale does not seem so unambiguous to the reviewer as to Gardner Clark. Yet, these are points for dispute and not all for authoritatively deciding on who is right or wrong.

Harry G. Shaffer—an economist not specializing in agriculture—takes issue with and quotes some Western, primarily U.S., extremely negative statements on Soviet agricultural performance and seems to imply that these represent an evaluation predominant among Western observers. At the same time, to prove his points, he quotes many equally Western publications, yet disregards the recent discussions on the merits or demerits of Soviet collectivization (Millar, Nove, Ellman, Grosskopf). His wording "human sufferings" (p. 58) hushes over the millions of deaths caused by Soviet collectivization, and he forgets to mention, when speaking of output growth, that still by 1950 the reluctantly tolerated private household plots produced nearly half of the gross total, and surely half of net agricultural output. Of the more than a few inaccuracies or doubtful interpretations of facts and figures, only a few examples can be pointed out here. Thus, Shaffer speaks of high rates of labor outflow from agriculture, allegedly indispensible for Soviet industrialization, but according to his own data, the annual average rate barely was an inconspicuous 1% most of the time. (See pp. 61, 79, and table 2.23, from which he wrongly deduces 24% over ten years, instead of 12%.) On page 81, he compares feed conversion rates per pound of gain in weight of calves over a certain age with total feed requirements per pound for raising a beef steer, and he misses the main point of Western deduction estimates from Soviet grain statistics, namely that

they serve to make Soviet "bunker" harvest data comparable to Western barn weight (p. 88). Following Shaffer's argument, one can but wonder why after the 1953 and 1964 changes in supreme Soviet leadership, agrarian policies came in for such harsh criticism by the Soviets themselves. Generally, it is not difficult to refute exaggerated statements of some Western observers (including the more naive cases of USSR-US comparisons), but Shaffer takes his points too far and, in a number of cases, simply errs in the opposite direction.

Victor Perlo pretends to put unfounded comparisons right—and makes highly doubtful comparisons, himself. Thus, in equalling (p. 109) the rate of U.S. (1850–1960) with Soviet (1928–75) urbanization speed, he is silent about the tremendous immigration in America and the periods of misery and starvation on the Soviet countryside. He enumerates reasons for collectivization (p. 111), which have little bearing on what happened in reality: efficient use of machinery (which actually was produced in sizable amounts only after collectivization), provision of a "surplus" of farm products (while the coercive system of extraction itself was proof of the nonexistence of a surplus), release of surplus manpower (for the actual outflow, see above), bringing closer the peasants and workers (whereas later Soviet statements testify to the existence of a deep gulf at least up to the mid-1950s). Perlo conceals that not only *kulaks* were terrorized during collectivization and attributes the resistance of the peasantry not to the Stalinist methods, but to "the pressure of world capitalism" (p. 112). He compares grain yields in the fertile Ukraine and Moldavia with U.S. average yields, which include large dry-farming areas (p. 115). One savors his contention (p. 137) that "anti-Communist revolts in Hungary [in 1956] . . . failed to win support in the countryside," while it is a fact, not disputed by Hungarian sources, that most collective farms in Hungary were spontaneously disbanded during 1956/57. These few of many examples may suffice. Yet it has also to be said that on some points Perlo's criticism of Western views is justified. Moreover, in his section on recent "Problems and Prospects," he gives a more balanced picture, thereby mirroring the Soviet treatment of the subject, which has become more realistic in recent times.

The concluding contribution to the volume consists of semi-official texts supplied by the Soviet press agency "Novosti." This text yields considerably less information than a selection of excerpts from some of the more sophisticated scholarly Soviet publications would have done.

Abstracting from Gardner Clark's contribution, the reviewer feels that the uninitiated reader will not gain a balanced picture from the volume as a whole, that the Sovietologist not versed in agriculture and the agriculturalist not knowing the Soviet Union may be induced to reconsider some too simple Western evaluations, and that the specialist in both fields is likely to find Shaffer's article provocative, but changing the more serious judgments only in some details. As to the rest of the volume, it is interesting as a Marxist partisan view.

Karl-Eugen Wädekin
University of Giessen,
Federal Republic of Germany

Necrology

Marlin L. Hanson, an economist with ESCS USDA, died 10 January in Washington, D.C. He was 48 years old.

Theodor Heidhues, professor at the University of Göttingen, Germany, died in Göttingen, 11 November 1978 after a long illness. He was 45 years old.

Joseph M. Johnson, professor emeritus, Virginia Polytechnic Institute and State University, died 22 April at age 61.

Sherman Ellsworth Johnson, past president ICEA and AAEA Fellow, died in April 1978 at 81 years. Johnson had been a deputy administrator of ERS USDA.

Donald R. Kaldor died 9 October 1978 at age 61. He was a professor of economics at Iowa State University.

W. J. "Aggie" Nucholls, associate professor emeritus, Virginia Polytechnic Institute and State University, died in Roanoke in March, aged 74.

Ben J. Pubols, retired agricultural economist with ERS USDA, died in Arlington on 17 December 1978 at age 79.

John L. Shipley, professor of agricultural economics, Texas A&M University-Amarillo Research and Extension Center, died 16 January at age 57 years.

Theodore S. Thorfinnson, retired agricultural economist with ERS USDA and professor of agricultural economics, University of Nebraska, died 29 January, at 84 years of age.

Harold N. Young, retired Director of the Virginia Agricultural Experiment Station and former head of the Department of Agricultural Economics and Rural Sociology at Virginia Polytechnic Institute and State University, died 23 October 1978, aged 83.

Statement of Ownership, Management, and Circulation (Act of 23 October 1962; Section 4869 Title 39, United States Code)

1. Title of Publication: *American Journal of Agricultural Economics*
2. Date of filing: 17 August 1979.
3. Frequency of issue: Quarterly and December Proceedings issue (February, May, August, November, and December). (*a*) No. of issues published annually: 5. (*b*) Annual subscription rate: $12.50; $25.00 and $35.00.
4. Location of known office of publication: Agricultural Experiment Station, University of Kentucky, Lexington, Kentucky 40506.
5. Location of headquarters or general business office: Agricultural Experiment Station, University of Kentucky, Lexington, Kentucky 40506.
6. Name and addresses of publisher, editor: American Agricultural Economics Association, Agricultural Experiment Station, University of Kentucky, Lexington, Kentucky 40506; Editor: V. James Rhodes, Department of Agricultural Economics, 200 Mumford Hall, University of Missouri, Columbia, Missouri 65211.
7. Owner: American Agricultural Economics Association, Agricultural Experiment Station, University of Kentucky, Lexington, Kentucky 40506.
8. Bondholders, mortgagees, and other security holders: none.
9. Nonprofit organization: Status unchanged during preceding twelve months.
10. The following circulation figures are provided for (*a*) the average number of copies of each issue during the preceding twelve months and (*b*) the single issue nearest to filing date:

	Average Copies	Actual Copies
Total number of copies printed	(*a*) 7,050	(*b*) 7,050
Circulation		
Sales through dealers, carriers, etc.	(*a*) None	(*b*) None
Mail subscriptions	(*a*) 6,278	(*b*) 6,278
Total paid circulation	(*a*) 6,278	(*b*) 6,278
Free distribution	(*a*) 3	(*b*) 3
Total distribution	(*a*) 6,281	(*b*) 6,281
Office use, leftover, inventory balance, etc.	(*a*) 769	(*b*) 769
Returns from news agents	(*a*) None	(*b*) None
Total	(*a*) 7,050	(*b*) 7,050

Information on Submitting Manuscripts

1. **Cover letter.** In a cover letter, the author(s) must state (*a*) that the material in this manuscript has not been published and is not being published or being considered for publication elsewhere, and will not be submitted for publication elsewhere unless rejected by the *Journal* editor or withdrawn by the author(s); (*b*) that the material in this manuscript, so far as the author(s) knows, does not infringe upon other published material protected by copyright; (*c*) that the employer of the author(s), if any, either does not assert an ownership interest in the manuscript or is willing to convey such interest to the American Agricultural Economics Association (AAEA); and (*d*) that submission of this manuscript gives the AAEA the exclusive right to publish, to copyright, and to allow or to deny reproduction of the manuscript, in whole or in part. If the applicability of point (*a*) is unclear, the author(s) should explain.
2. **Author's identification.** In order to protect their anonymity in the review process, authors should avoid identifying themselves in the manuscript. Attach a separate page including the names of the author(s) and appropriate biographical information, as well as the title of the manuscript. Include only the title on the first page of the text.
3. **Typing.** Double-space all material, including footnotes, tables, quotations, and references, on 8½-by-11-inch standard weight white paper with margins on all sides of at least 1¼ inches.
4. **Style.** Follow *A Manual of Style* by the University of Chicago Press as well as previous issues of this *Journal.*
5. **Mathematical notation.** Use only essential mathematical notation; such notation is costly to typeset and may limit the readership. Avoid using the same character for both superscripts and subscripts, using capital letters as superscripts or subscripts, and using overbars, tildes, carets, and other modifications of standard type. Asterisks, primes, and small English letter superscripts are suitable substitutes.
6. **Footnotes.** Number footnotes consecutively throughout the paper, not page by page. Type the footnotes, double-spaced, on a page following the article. The institutional paper number and acknowledgments, if any, should be placed at the beginning of the list of footnotes. Footnotes should be only explanatory and should not be used for citations or for directing the reader to a particular work. This information can be incorporated into the text itself.
7. **References and citations.** Place all references, alphabetized by author, in a list at the end of the paper entitled "References." Only cited works should be included in the reference list. All citations should appear in the text and contain the author's name and page numbers, when necessary. Citations can be inserted parenthetically, e.g., (Doe) or (Doe, p. 5). Specify the date of publication if the same author appears more than once in the reference list, e.g., (Doe 1971, p. 5). If the author's name appears as part of the sentence, a parenthetical reference is unnecessary unless you need to cite page numbers or a date. A style sheet on references and citations is available upon request.
8. **Tables.** Place each table on a separate page; double-space all material; omit vertical rules.
9. **Figures.** Prepare figures on heavy white paper or acetate sheeting using black India ink or paste-up types suitable for black and white reproduction by a photographic process. Typescript is not suitable.
10. **Three copies.** Send the typed original and two carbon copies or photocopies. All copies should be inspected for completeness and quality of reproduction.
11. **Abstract.** Instructions for the preparation of an abstract will be sent when the manuscript is accepted for publication.
12. **Page charge.** Major support for this *Journal* is provided by page charges of $40 per printed page, or fraction thereof, payable by the supportive institution or granting agency. Payment does not affect acceptance, scheduling, or form of publication. Instructions for making payment are provided with galley proofs.

American Agricultural Economics Association

Objective

The AAEA seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy. The activities of the AAEA include:

—publishing the *American Journal of Agricultural Economics;*
—planning and conducting two annual meetings of the membership;
—sponsoring annual awards for outstanding extension programs, distinguished teaching, and outstanding research;
—recognizing outstanding agricultural economists through a fellows program;
—supporting a literature retrieval system in cooperation with the U.S. Department of Agriculture;
—publishing periodically a biographical directory of the AAEA's members;
—supporting an employment registry for agricultural economists in cooperation with the U.S. Department of Labor.

Membership and Subscriptions

Membership in the AAEA is open to individuals having a professional interest in agricultural economics. Dues, payable at the beginning of each calendar year, are as follows: regular members, $25, senior members, $12.50, and junior members, $12.50. Senior membership is open to persons, upon written request, who are sixty-five years of age or older and have retired from active professional work. Junior membership is for students and is limited to three years; students should use application forms available from and signed by the head of the department in which they are studying. Members receive this *Journal*.

Any firm, corporation, association, or partnership may become an institutional member upon payment of $100 per year; institutional members receive three copies of each issue of the *Journal*. Library subscriptions are $35 per year. Individual issues of this *Journal* are $10.00.

Payment of membership dues, correspondence regarding subscriptions, orders for individual copies of the *Journal*, changes in address, or inquiries about the general affairs of the AAEA should be sent to John C. Redman, Secretary-Treasurer, American Agricultural Economics Association, Department of Agricultural Economics, University of Kentucky, Lexington, Kentucky, 40506.

American Journal of Agricultural Economics

Volume 61 Number 4 Part 2
November 1979

In this issue: Proceedings from the Economic Research Conference on U.S. Food System Regulation held 16–18 April 1979 at Airlie House, Virginia

Staff for volumes 60–62

Editor
V. James Rhodes
University of Missouri-Columbia

Associate Editor
Stanley R. Johnson
University of Missouri-Columbia

Book Review Editor
Herbert H. Stoevener
Oregon State University

Assistant Editor
Martha A. Luzader
University of Missouri-Columbia

The *American Journal of Agricultural Economics* is published five times a year (February, May, August, November, December) by the American Agricultural Economics Association. Prior to 1968, this *Journal* was the *Journal of Farm Economics.*

Printed for the AAEA by Heffernan Press, Inc., Worcester, Massachusetts, USA.

Second class postage paid at Lexington, Kentucky, and additional mailing offices, Pub. No. 019500.

Editorial Policy

The purpose of the *Journal* is to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscripts should have a relationship to the economics of agriculture, natural resources, or rural and community development. Contributions, methodological or applied, in the business, extension, research, and teaching phases of agricultural economics are equally encouraged.

Editorial Communications

All manuscripts and editorial correspondence, except as noted below, should be addressed to the editor, V. James Rhodes, Department of Agricultural Economics, Mumford Hall, University of Missouri Columbia, MO 65211

Communications concerning book reviews and books submitted for announcement in the *Journal* should be sent to the book review editor, Herbert H. Stoevener, Department of Agricultural Economics, Oregon State University, Corvallis OR 97331.

American Journal of Agricultural Economics

Volume 61 Number 4 Part 2
November 1979

Special Editor
Victoria S. Smith

Foreword

This special issue of the *American Journal of Agricultural Economics* contains papers presented at the Economic Research Conference on Regulation in the U.S. Food System. The conference was held at Airlie House, Virginia, 16–18 April 1979. It was sponsored by the American Agricultural Economics Association, the Economics, Statistics and Cooperatives Service of the U.S. Department of Agriculture, the Farm Foundation and NC-117, the Food System Research Group located at the University of Wisconsin, Madison.

The purpose of the conference was to stimulate the interest of agricultural economists in doing research on regulatory issues relating to agriculture and the food system. The conference had four sessions. The purpose of the first was to define regulation, putting it within a theoretical context. Speakers in the second attempted to isolate the role of economic research in the decision-making process. The goal of the third was to develop a research agenda in the regulatory area. During the fourth, speakers discussed a wide variety of regulation research issues—issues which deserve the attention of agricultural economists.

Speakers were drawn from a wide variety of backgrounds, both within the agricultural economics profession and from outside. In order to provide a view on how economic research on regulation can be useful in the public decision-making process, the speakers included people directly involved in that process.

The sponsors appreciate the decision of the *American Journal of Agricultural Economics* to publish these papers. We hope the information provided at the conference and the issues raised there will serve as a catalyst for future economic research in food system regulation. Our special thanks are extended to Vicki Smith, conference coordinator and the editor of this issue.

Richard King
American Agricultural Economics Association

William T. Boehm
Economics, Statistics and Cooperatives Service

R. James Hildreth
Farm Foundation

Dale Dahl
NC-117

The Economics of Regulation
(R. James Hildreth, Farm Foundation, Chairperson)

Observations on the Political Economics of Regulations

James D. Shaffer

This conference on regulation responds to a demand for better understanding of the U.S. regulatory system. Public officials, business leaders, news reporters and citizens in general are raising serious questions about existing government regulations. Questions are raised about the benefits and costs, the complexity, the apparent irrationality, the unanticipated outcomes and failures to achieve perceived objectives. At the same time newly defined problems and public concerns, and new groups with political awareness and power have created a demand for additional regulations.

I assume that to regulate means to control, to direct, to govern directly and indirectly. To define regulation broadly emphasizes the ubiquity and complexity of regulations and focuses attention on alternatives and problems in regulating economic behavior rather than on the meaningless question of whether to regulate or not. It focuses attention on the political economy as a regulatory system.

Economic behavior is regulated in many ways. Resources are never allocated simply by the market. A regulatory system is always assumed. It is useful to think of the market as an instrument of regulation rather than an object of regulation. Prices always reflect political decisions defining inputs and outputs, and what has to be taken into account in economic decisions. The law and economics are inseparable.

Modern economists have had a tendency to avoid the difficult issues of regulation by assuming large parts of the law as given. The ideology of *laissez-faire* has continued to influence economic analysis and the discussion of economic policy even though the modern political economy has little resemblance to an idealized, unregulated, competitive market. Perhaps the idea that our economic system operates in some magical way with production controlled by preferences expressed principally through the market has tended to divert attention of economists from the study of market phenomena in terms of their regulatory underpinnings and to minimize the study of the extensive use of nonmarket mechanisms in allocating resources. The politics of regulation and the economics of political power are central aspects of a realistic study of resource allocation. This conference on regulation hopefully will contribute to a better understanding of the relationship of law and economics.

In this paper I comment upon the concept of the unregulated competitive market as a norm, discuss the nature of regulation and the regulatory process, suggest concepts which seem to be relevant for developing a theory of regulation and briefly comment on some relevant research. The focus of attention is on economic and political behavior in the modification of the regulatory system and in response to regulations.

The Unregulated Competitive Market

First let me express a concern: much of the research and debate on regulation seems to be out of context. The concept, objectives, and consequences of regulation are often narrowly defined. Simplified models, abstracting from the complex reality of the regulatory process, are sometimes inappropriately used in policy debates. It is often assumed that preferences expressed through political processes are less legitimate or perhaps less accurate expressions of real preferences than those expressed through market processes, ignoring the fact that the market always reflects political decisions as well as the decisions of individuals

---

James D. Shaffer is a professor of agricultural economics, Michigan State University.

Michigan Agricultural Experiment Station Journal Article No. 9040. The author wishes to express appreciation for helpful comments on an earlier draft of this paper to C. Kramer, D. Dahl, A. Schmid, P. Wandschneider, D. Ricks, L. Libby, W. Samuels, B. Ferres, and C. Cordes.

seeking their individual advantage in the market.

Let me quote a few sentences from recent reports which illustrate the cause of my concern. A report on the regulation of railroad grain rates states: "Much of this analysis hinges on two assumptions drawn from basic economic theory. First, perfectly competitive markets serve to optimize efficiency in allocating resources and forming prices. Thus, opportunity costs of production and income redistribution effects are minimized for society under such a market structure. Recognizing that no existing market is 'perfectly' competitive, one can still argue that *any* move toward more effective competition or any move that serves to stimulate competition will have positive social benefits" (Martin and Dahl, p. 9). It appears that the competitive model is posited as a norm and a regulation is judged against this norm. Actually, the study makes useful comparisons of costs among modes of transportation, given all the rules and entitlements which define costs, and shows the effect of rate regulation on the selection of mode. The competitive model norm is not needed to make this point.

The *Study on Federal Regulations* by the Senate Committee on Governmental Affairs, a report which provides significant insights into the problems of federal regulation and recognizes objectives other than "efficiency," begins a chapter with the statement: "Unregulated markets can, under proper circumstances, result in an efficient allocation of resources" (U.S. Congress, p. 9). And under the heading "Effects of controls on resource allocation and efficiency" it states: "Prices above or below competitive levels do cause a net loss to society . . ." (U.S. Congress, p. 58). This is but an example of the frequent implicit use of the competitive model as a social norm and the facile use of that fictional concept, the unregulated market.

What does an unregulated competitive market mean? Does it mean the absence of rules affecting economic behavior? Does it mean an absence of property? If so, what would be traded? Would there be no rules defining fraud? Would there be no rules about liability? Would there be no rules legitimizing the corporation? Would there be no legal tender? Would there be no rules in regard to peonage? Obviously this is not what is meant. Some existing set of rights, rules, laws—that is, a regulatory system—is assumed, taken for granted or ignored in any analysis of regulation.

I use these examples only to show the need to make a point which has often been made and should not require repeating. There is no logical basis for normative statements that regulations which are inconsistent with the structure of the perfectly competitive model necessarily reduce welfare. It is not logical to assume the institutions and distribution of wealth and power to be given, and to remain thus unevaluated, and then to use the model to conclude that a particular rule which affects such distribution reduces total welfare. This is a judgment that one set of rights is better than another and should be acknowledged as such a judgment.

In addition, the theorem of "second best" postulates that a rule to make a market more nearly meet the conditions of a perfectly competitive market will not necessarily lead to improved welfare within the context of the theory unless all the other conditions of the competitive market are met. Such conditions are never met in the real world.

It is instructive to think of the set of regulations that would be necessary to establish the conditions of a perfectly competitive market. Clearly all markets are regulated. Regulation is not a means of dealing with market failure; without regulation in the broadest sense there would be no market.

What Is Taken into Account?

Economists now possess the foundation of a framework useful in contributing to the analysis of regulatory systems and problems. Economics as a behavioral science predicts behavior and some of the consequences of behavior in response to a set of constraints. The usual assumption is that individuals seek utility, but more usefully the assumption is that individuals and groups have objectives which are sought within a set of physical and institutional constraints. The literature of institutional and public choice economics is concerned with the question of the relationship of institutional constraints—what has to be taken into account—and certain aspects of performance. Understanding the interaction of individuals as a system allows economists to predict certain outcomes.

Some consequences of behavior are taken into account and some are not. Those which

are not are referred to as externalities and bringing the externalities into account is called internalizing the externality. It is generally accepted among economists that an appropriate role of government is to internalize externalities. The argument goes that if property rights are structured so that benefits and costs are considered by the decision makers then market interaction will lead to appropriate resource allocation. Rights do determine what is taken into account in decision making. The underlying principle is powerful. However, the simple prescription to internalize consequences begs the question. Externalities are ubiquitous. The question is, which consequences are to be counted by whom? For example, inflation is an important consequence of economic behavior. Should this consequence be internalized by making it illegal to impose this negative externality? Does that imply wage and price control? Or should my mother be able to sue for the theft of her savings due to inflation? A consequence of high consumption of energy by those who can afford it is that the poor may not be able to heat their homes. Should this consequence be internalized? It may be argued that this is an equity question and should be dealt with by income transfers. But taxes and transfers also have effects on incentives and, thus, consequences for resource allocation.

The public good is characterized by a just society as much as by a national defense. How can the benefits of a just society be internalized so that we produce the appropriate amount of justice? Endless examples could be given. Let me restate my point. Economic activity produces many complex products or consequences. The incidence of the benefits and costs is affected by rights. The rights system is selective of the benefits and costs which are internalized. It is neither possible nor desirable to internalize and privatize all consequences. There is no avoiding the political decisions about rights and thus making collective judgments about the desired performance of the economy. Schmid, in his book *Property, Power and Public Choice,* provides an in-depth discussion of these issues.

Behavioral psychologists argue that individual behavior is shaped by the consequences of particular patterns of behavior. That is, individuals learn as a result of the benefits and costs associated with certain behavior. An individual's environment consists of complex "if . . . then" situations. If the individual responds with particular patterns of behavior then the environment will respond with positive and negative payoffs. For example, if the proper coin is inserted in a vending machine the reward is a soft drink. Obtaining the drink is contingent on inserting the coin. This is an important concept. Regulations change the contingencies of reinforcement in individual environments. They change what is taken into account. They affect the benefits and costs, associated with individuals' patterns of behavior. At the most fundamental level, then, the study of regulation is the study of the relationship between regulation and the benefits and costs to individuals, the response of individuals to this pattern of benefits and costs, and the aggregate consequences of this behavior, which we will call performance. Regulations structure the opportunity set and thus shape behavior and consequently performance.

Types of Regulations

In my struggle to understand the nature of the regulatory process I find it useful to review the types of regulation and to contemplate an analytical framework which would relate these regulations first to economic behavior, and then to performance.

Laws

A great body of common and statutory law establishes a set of rights and obligations. These laws determine whose interests or preferences get counted, what is considered a cost and what part of output the producer may keep, be rewarded for, or be liable for. For example, the law defines theft. If a poor man snatches my mother's purse and takes $10, that is theft. If those with economic power increase prices resulting in the loss of half the value of my mother's savings, that is not theft, but inflation. If my cow gets out I may be liable for damage she causes my neighbor. If I adopt a new technology and my neighbor loses his job because of it, I will not be liable. If I overgraze my land and the soil erodes leading to dust storms and higher food prices result, I am not liable for the damage to others. I may or may not have to pay for water, will probably not have to pay for dumping some chemicals in the air and would probably have to pay for dumping junk in a dump. A prostitute may not be allowed to sell sexual services, but executives of a TV network can produce a show

called "The Newlywed Game" and debase the culture using a property right to the channel, granted and protected by the government. Examples could go on and on. The point is that laws of property, liability, bankruptcy and the like establish contingencies of reinforcement by influencing what is considered a cost and benefit. To own something permits the owner to impose a cost on someone else and to claim benefits from it. A common law rule enforced by a district judge is just as much a regulation of economic activity as a rule promulgated by the Environmental Protection Agency (EPA).

Customs

Closely related to the common law and basic property rights is a great variety of customs and practices that regulate economic behavior. Most rights are defined and respected as a matter of custom or socialization. The common law is in part a reflection of customs and the contingencies of the law are important in the socialization process. Customs defining rights are a part of the common law in the sense that that which is not prohibited is allowed or protected. Many private practices, in addition to the usual notions of property, regulate economic behavior. Examples are: the custom of requiring an education credential for jobs unrelated to the underlying education; personnel selection and promotion practices which advantage some groups and discriminate against others; "red lining" areas or groups in granting credit. The monetary-credit system—where money is created—can grant funds to selected groups who then can bid real resources away from others, and define property rights. This is a part of the regulatory system which is based on business practices and customs.

Standard Operating Procedures

Firms adopt many standard operating procedures which regulate economic behavior. Accepted practices in the allocation of costs in multi-product firms provide one example. Private cross-subsidies are extensive. A grocery store has many different margins meaning that it is charging different prices for the same services. Posner has an interesting article discussing what he calls taxation by regulation. He points out that one of the results of regulation of common carriers and public utilities is, in effect, to tax some customers and then use those taxes to subsidize service to others, that is, cross-subsidizing. But private companies do this consistently as a matter of practice. If cross-subsidies were enforced by government or if cross-subsidies were to be prohibited by government it would be called regulation of the market. My argument is that the private practice of cross-subsidization is in effect a right and is functionally similar to regulation as described by Posner. Without reference to common practice, cross-subsidies cannot even be defined, for overhead costs are not linked to particular units or kinds of output. The possible list of customs and practices which regulate economic behavior would be a long one.

Taxes, Payments and Services

Another major set of governmental actions regulating economic behavior is taxes, subsidies, transfers and government provision of goods and services. Taxes create a great variety of contingencies which are functionally equivalent to direct regulation and common law property rights. We have even coined the word tax subsidy for the case where a tax is not imposed as a reward for some behavior. Taxes, which currently represent about one-third of the U.S. Gross National Product (GNP), influence almost every economic activity, promoting some and inhibiting others. A study of the regulatory aspects of taxes on the food system would be a very big study. Similarly, subsidies and transfers are extensive and are often designed to regulate behavior. Subsidies and tax advantages foster cooperatives, for example. Perhaps the most direct government control of economic activity is public ownership and direct provision of goods and services.

It is useful to consider taxes, subsidies, transfers and government provision of services as a group because they are obviously interrelated. Taxes (or a fiscal deficit) are necessary to finance the others. A decision to achieve an objective by providing a subsidy, for example, should be made with knowledge of the effect of the supporting taxation as well as the subsidy. The unintended consequences may be more important than the intended. The intent behind imposing taxes or making transfers may not be to regulate but the regulatory consequences are real nonetheless; both affect economic incentives.

Statutory-Administrative Rules

Finally, there is a broad class of statutory-administrative regulations. These are the governmental rules which are most often thought of as regulations. It is difficult to differentiate this type of regulation from rights. Rights are always reciprocal in the sense that a right implies the obligation of others to respect the right. And rights are always limited by other rights and rules. Statutory-administrative regulations define rights and obligations. These include regulations dealing with competition; rates and quality of service; collective action by unions, cooperatives, corporations; consumer protection; worker health and safety; environmental protection; money and credit; and many other areas of life.

Toward a Taxonomy

All of these types of regulations are functionally equivalent in the sense that they govern economic behavior by influencing what is taken into account by decision makers. There are, of course, significant differences among these types. A taxonomy would be useful. Let me mention some of the elements of such a taxonomy.

(*a*) The enforcement mechanisms. Civil or criminal sanctions can be used. The courts can be the first or the final resort. A specific agency can be created to achieve the regulatory objectives.

(*b*) Regulation of structure, conduct or performance. A set of rights establishes a structure for market interactions. Given the structure of rights, preferences are articulated through the market process. Regulation of conduct usually involves a lesser reliance on market processes for preference information. Regulation of performance attempts to specify the outcomes or product more directly by the political process.

(*c*) The degree of specification. This element involves the use of specific versus performance standards. For example, in attempting to provide worker safety two extremes of specification are first, the common law principles of employer liability for damages to a worker and second, establishing detailed rules relating to work environments and worker behavior.

(*d*) The nature of the incentives. The choice is between negative and positive reinforcement.

(*e*) The nature of the contingencies for application of the regulation. For example, the application of a marketing order to a group of growers is contingent upon a vote of the growers. A subsidy may be contingent on compliance with other regulations. Some regulations are voluntary. It is possible to avoid some regulations by avoiding an activity.

(*f*) The jurisdictional boundaries. What unit of government adopts and applies the regulation and how is the regulated group defined? This has important implications with respect to external effects and effectiveness.

Perhaps the most important dimension of a regulatory system is the way in which political and market processes are combined in articulating the preferences and in searching the production opportunity set. An enterprise system offers incentives to identify and cater to individual preferences and to search for means of meeting those preferences. The political system provides the rules which make the game possible and influence the outcome in order to meet politically defined standards of performance.

This is not a complete list of either types or dimensions of regulations. There are many types of regulations. The design of regulations offers many options, and regulation has many different objectives. Economic behavior is governed in many different ways.

I am attempting to convey an impression of the problems involved in analyzing the regulatory system and to suggest an approach to the analysis. I believe it is essential to understand that the market is never unregulated and to understand the market as an instrument of the regulatory process rather than an object of regulation. Consumers and producers respond to prices, and prices always reflect both politically determined rights, defined by a set of rules, and the interactions of those who have rights as they exercise their options to buy, sell, use, and produce. Thus, the market translates political decisions into economic incentives.

The Regulatory Process

The previous sections made observations about the nature of regulations. This section contains observations about the regulatory process. By the regulatory process I mean the processes by which regulations are instituted. I will discuss some characteristics of the sup-

ply and demand for government regulations.[1] This includes both enactment and implementation.

The analysis of the regulatory process requires the identification of participants and characteristics of their motivation and behavior. It is useful to identify participants by classes based upon roles. The major roles to be considered are citizen, consumer, firm manager, worker, political party, legislator, the bureaucracy, the judiciary, and the media. In the study of a particular problem or area of regulation the participants would need to be more specifically identified. The participants operate in an environment which shapes their behavior. The environment includes physical constraints, an inherited institutional structure, an ideology, and great uncertainty about both the effects of existing and proposed regulations.

The regulatory system evolves. It has a history. A regulatory system and ideology supporting that system are inherited. Much of it remains unevaluated most of the time. Changes in the environment such as new technology, availability of resources, changes in distribution of wealth and power, extent of the market, new knowledge and ideas about the effects of the current system and potential benefits from new institutional arrangements create a demand for change in regulations and incentives to supply them. A theory of regulation would require consideration of this evolutionary process.

The key concept is a simple one. The behavior of individuals and groups is governed by the consequences of their behavior: feedback modifies the system. Not only is performance of the political economy the product, but it is the major input to the evolving system. Preferences, regulation, ideologies cannot be treated analytically as exogenous to the system for they are both input and output.

The Government Regulation Enterprise

Consider government as an "enterprise" which supplies regulatory services. It responds to demands for particular regulations or outcomes, and it provides regulatory implementation and enforcement. Like all complex organizations government is operated by many types of participants, each with his or her own preferences and ideologies, responding to unique opportunity sets or contingencies of reinforcement.

Elected policy makers, legislators, and executives are constrained by the necessity of being elected. Each is an entrepreneur promising to deliver benefits to constituents in return for votes. The incentive will not necessarily only be to maximize votes. Officials have their own views as to characteristics of a good society and have interests which may be different from those of some of their constituents. In order to be elected, an individual must have money and other resources, thus election support is provided by individuals and groups seeking influence in promoting their own interests. The rules and technology of elections affect the outcome. For example, the development of TV, which has great capacity for influence and is expensive, changed the patterns of influence. Votes are based upon anticipated services. Those seeking election attempt to identify products which will sell, and they also promote their products, like private firms.

There is a great deal of slack in the system, partly due to uncertainty and ignorance. Voters have great difficulty in identifying what an official does and an even greater problem in identifying the consequences of what is done. There may be little connection between what is promised and what is delivered. There is limited accountability or voter protection. Competition creates an incentive for officials to promise to solve all problems, often with regulation of some type, and to vote for regulations which have uncertain outcomes. This may explain some of the proliferation of regulations.

Because of the uncertainty as to both constituent preferences and outcomes of specific regulations, officials are responsive to information about both. This creates a demand for information and potential benefits for those who supply needed information. A lobbying enterprise provides subsidized information and sells influence. The result is differential influence among groups related to wealth and concentration of interests. It can be expected that elected officials respond to material incentives within a code of ethics, the same as businessmen or workers. Thus, they may be influenced by the prospects of future employment or other inducements.

Regulations are promulgated and im-

[1] The observations are drawn from many sources but special reference should be made to Bartlett and Stigler.

plemented by agency bureaucrats, the courts, and the police within a general legislative mandate. The effect of a law on behavior obviously depends upon how it is enforced. Enforcement is often selective and subject to influence. The Sherman Act, for example, does not determine which firms are selected for anti-trust prosecution. A set of rewards and constraints operating on the lawyers in the Federal Trade Commission does. Wellford has made an interesting study of food safety regulation in which he describes the contingencies of reinforcement for meat inspectors which included bribes and threats on the job and pressures from superiors who do not want to upset the industry. This is part of the reality of the regulation of purchasing agents by private sales agents.

Administrative procedures acts are instituted to regulate the procedures of regulatory agencies in promulgating regulations. These acts affect the flow of influence in establishing specific rules by determining hearing and legislative review procedures.

Regulatory agency bureaucrats have goals of their own. For example, bureaucracies create a perverse incentive by rewarding managers according to size of staff and budget. One way of expanding both is to extend the scope and intensity of regulatory activity. Thus, both legislators and bureaucrats may expand the supply of regulations independent of original citizen preference. This is the same as the dependence effect in the private economy where producers influence the demand for their products.

The rôle of the courts in regulating economic behavior is, of course, complex. Influence is involved in the selection of judges but the influence system is quite different than for the legislature. Judges make regulations, interpret regulations and give orders enforcing regulations. That great body of rights regulating economic behavior known as the common law is in their hands. When the courts are slow in adapting the common law to changing political preferences, legislatures may respond with statutory law. The position of judge requires behavior which probably makes the judge less subject to immediate influence of concentrated interest than other regulatory participants. At the same time, the costs of litigation and the advantage of superior legal services seems to bias the system in favor of the concentrated rather than dispersed interests.

Demand Articulation

In the market for products, effective demand reflects both preferences and ability to pay. Preferences of different people receive differential weights. Similarly, the demand for government regulations reflects both preferences and ability to influence the government, the supplier of major classes of regulations. Thus, the economics of political influence is a major aspect of the demand for regulations.

Citizen behavior is similar to consumer behavior in that much of it is habitual. Preferences are learned. The demand for regulation is embedded in ideology. Citizens learn concepts about the characteristics of a good society. This concept changes with experience as the conditions in the physical and social environment change. Just as in the case of the demand for products in the market, the demand for regulation is affected by the products which are supplied and promoted.

There are problems in articulating preferences. Individuals may lack incentive to investigate and weigh the costs and benefits of a vote because the consequences of the vote are not clear or immediate. Transaction costs are high in political decision making. Each voter cannot afford to analyze the costs and benefits of every decision made by government, thus it is necessary to vote for representatives to express preferences for the group. This creates what is sometimes referred to as the problem of the blue plate special. The voter must choose between candidates with a bundle of characteristics, some he likes, some he dislikes and many about which he knows nothing. The product of the political process also has the characteristics of a public good: each within a jurisdictional boundary gets the same regulatory system whether they like it or not. And the nature of the voting process is that all who are franchised get to vote whether they use the product or not. Thus, it is difficult to express intensity of preferences.

Because of the economy of representative government, representatives are required, but representatives have motives of their own. One of these motives is to get elected. Getting elected is facilitated by belonging to a political party. Where the party is strong voters may vote for the party rather than the candidate.

The political party is a complex organization which does more than sell influence to those who finance it. In attempting to organize support of large groups, it collects information

about preferences, and works out compromises. It provides discipline. It identifies an ideology and an image. It has many participants, each of whom has incentives independent of those of the organization.

In addition to political parties, there are independent political entrepreneurs who make a career of influence production by representing such dispersed interests as the consumer activist and poor peoples' lobbies. And there are movements, such as women's liberation, and special single interest groups such as the National Rifle Association attempting to influence specific regulations. Again, each of these involves participants with different positions and roles operating under specific contingencies of reinforcement. A theory of regulation that did not include subtheories on social movements and political parties would not be complete.

Almost all voters have a stake in regulation both as consumers and producers. For most, the interest in any particular regulation is greater as a producer than as a consumer. Large corporations would be expected to possess both the incentive and resources for influence. It is assumed that firms which have an incentive to maximize profits will spend resources to influence regulation in their favor if the return per dollar is better than than spending it on the next best alternative. Since the rewards may be substantial, the industry incentive to influence regulation is also substantial. At the same time, the benefits to individual citizens are small relative to the transaction costs of organizing influence in opposition to the regulated firms. Few voters will oppose a politician simply because he does not put pressure on a regulatory agency on a particular rate decision. Thus, it is reasonable to expect more resources to be allocated to influence representatives to favor producer interests. These principles could be generalized to an economic theory of the captured regulatory agency. They also have implications for anti-trust policy.

The transaction costs for collective action for some groups are smaller than for others. Groups already organized for other purposes or brought together by some other collective good would have an economic advantage in producing influence. Unionized workers, for example, would be expected to devote more resources to political influence than the nonunionized. Where unions and corporations have a common interest, such as in a trade restriction, they would be expected to combine resources for influencing the rule.

The economics of influence suggests that dispersed groups like consumers have relatively more influence in getting a bill passed than in the more difficult and long-term job of monitoring and influencing the implementation of a regulation. Regulations affecting consumers directly and noticeably would be more likely to be the focus of consumer influence and thus to favor consumer interests than those with more indirect effects.

Another set of participants is those who work in the news media. The selection and treatment of news have a pervasive influence on the political system and thus the regulatory system. Political participants attempt to avoid actions leading to bad press and they seek favorable publicity. Media participants also operate under a unique set of incentives and constraints involving advertising, professional associations, news sources, rating services, public relations firms, and their own ideologies. The emergence of the local monopoly and chain newspapers and of television, with its unique power to influence, is a recent development which is greatly influencing the regulatory system. The news media coverage of an accident involving a chemical fire retardant in the Michigan food supply significantly influenced legislation designed to regulate that chemical and other toxic substances. To predict changes in regulation one would need a model to predict news media behavior. The news media alter the opportunity set within which elected officials, bureaucrats and firm managers make decisions.

In this system of influence what can be said about the articulation of voter preferences? It appears that in a complex democratic society the majority of citizens express preferences very indirectly. It is difficult for them to know what elected officials do, let alone what the consequences of those officials' actions will be. What they do know is how the political economy is treating them. They have concepts about performance, and, since enough citizens will vote against what they believe to be poor performance, elected officials and parties will attempt to deliver an acceptable product. This relationship is not too different from that between the stockholders and management of a large corporation. If the management performs reasonably well it gets little attention

from the stockholders. If performance is below some acceptable standard the management is in trouble.

A recent article reports results of opinion polls regarding certain types of national regulations on business (Lipset and Schneider). They conclude that voters are becoming more sophisticated about benefits and costs of these regulations, and support regulation in a number of areas. They report a 1978 survey which found a much higher percentage of "yes" to "no" answers to the question of whether costs added by regulations are worth it if they: protect workers' health and safety; protect workers' pension plans; ensure safety, and dependability of products or services; ensure equal employment opportunities; and protect the environment. Another finding of special interest results from their review of opinion data since the 1930s. They conclude that Americans have ambivalent attitudes toward regulation. Their opinion data has indicated that a majority opposes more regulation in general, but, even as more regulations have been enacted, a majority has also voiced approval of specific existing regulations and indicated support for keeping those regulations in effect. I realize this is weak evidence but it implies to me that the political system has responded to preferences for regulation and that the preference expression in the polls was based upon perceived consequences of regulations not specific regulation. It may also suggest that the supply of regulations creates its own demand.

About Research

The study of regulations has the burden of evaluating and predicting the consequences of alternative configurations of regulations. It must be recognized that the output of the analyst is an input to the evolving system. Thus, the researcher is an important participant in both the influence system affecting the demand for regulations and in the production of regulations. There is no escaping that fact. The selection of methods and problems carries a social responsibility.

The research agenda implied by this perspective is enormous. As in all economic behavior, choices must be made because of the reality of scarcity. I suggest high priority be given to development of theory and description of the evolution of the regulatory system. This will require behavioral models of important components of the system. To adequately understand and predict the development and consequences of regulations we need at least minimal behavioral theories of voting, markets, firms, households, political parties, bureaucracies, courts, unions, and social movements.

For example, it cannot be assumed that regulations of firm behavior will have intended consequences. Assuming firms will maximize profits is not enough. Firms develop standard operating procedures and an ideology which influence their responses to specific regulations. It can be expected that they will attempt to influence both the design and the implementation of the regulations. They will anticipate regulations and their response to the expected regulations may have significant consequences. Clearly an understanding of the behavior of the firm is required.

My observations on the behavior of important groups in the political influence system should be taken as hypotheses grounded in observations of the real world but not carefully done analysis. A good deal of research has been completed, but it has not been integrated, partly because it has involved different disciplines.

A good taxonomy of the regulatory system is essential. Comparisons of consequences generally associated with alternative types of regulation would be very useful. At least we need to develop systematic ways of analyzing the alternatives. Interesting work has been done analyzing alternative approaches to regulation for environmental quality—comparing specification standards, performance standards, marketable rights and pollution taxes, for example. It would be useful to compare the effects of requiring commercial insurance to protect workers to the detailed standards for worker safety as applied by the Occupational Safety and Health Administration (OSHA). Many examples could be listed.

We need research examining the mechanisms of political preference articulation. Such research would include study of the economics of political and jurisdictional boundaries. This kind of activity is especially appropriate for economists because it involves the familiar subject of externalities. There are also a variety of institutions which might be developed to provide policy makers with critical information about citizen preferences.

We need studies of the performance of specific subsectors of the economy. Develop-

ing relevant dimensions of performance is itself an important research task. Then links need to be established between sets of regulation and performance.

Realistically, most of the analysis of regulation will contribute to diagnosis and prescription in response to specific political demands. This is extremely important work. I know of no substitute for detailed analysis which attempts to identify all of the relevant groups of participants and asks how specific rules change the consequences of their behavior, predicting in turn how this will affect the performance of the larger system. My observation is that much of the so-called failure of regulation has resulted from unintended consequences due to failure to understand the behavioral responses of critical participants. Good intentions are not enough and legislating well-intended regulations without attention to the details of design and the real consequences for participants is never enough.

The problems addressed in the discussion of market failure are critical ones. I believe, however, that they should be understood as problems of regulation. The problems are created by the fact that individuals and groups seeking their advantage in the short run produce consequences inconsistent with the long-run well-being of the group. Microeconomic behavior leads to undesirable macroeconomic results. The diagnostic function of regulatory analysis is to identify such situations in the political economy. The prescriptive function is to identify alternative institutional designs more congruent with politically articulated standards of performance.

Finally, let me briefly discuss an important contemporary problem from this perspective. Almost every group in the political economy has developed a capacity to protect its nominal position in the income distribution by a threat to collectively withhold services, by restricting production, or by somehow indexing its right to a flow of income to a measure of inflation. Many of these protective practices by firms and workers reduce productivity. The capacity to protect nominal shares of income derives from the structure of the regulatory-rights system. This is usually the right to collective action or to administer prices. At the same time the prices of natural resources, especially oil, have increased and the costs of worker safety, product safety, and environmental protection have been shifted and have to be paid for by new groups. No group seems willing to pay these added costs if it decreases their real income. We are perhaps trapped by unrealistic expectations of continuing increases in real personal income as measured by direct goods and services. In addition, many areas of economic activity, including governmental, are not under control of the aggregate consequences of their behavior. The dynamics of this situation lead to inflation, unemployment and reduced output (compared with potential).

The general diagnosis of this problem is, of course, much easier than the prescription. From the perspective of this paper it is suggested that many regulations need to be examined, first for their impact on raising prices, second for possible changes in them and the consequences of such changes, and third for the political feasibility of change which may require some political trade-offs. For example, hospital costs have risen more in recent years than any other major component of the price index. Even a casual study indicates that the consequences of the increased costs do not fall directly on those who make the decisions. About 91% of hospital costs are paid for by third parties, either governments or insurance companies. Even the insurance costs, which are affected by use of hospital resources, do not fall directly on the decision makers—the doctors, patients, and administrators—because of the fact that hospitalization insurance as a fringe benefit is not taxed and thus this benefit appears free to the users. Simply changing this tax situation would at least bring some of the consequences of hospital decisions to bear on those who make decisions. Of course, many other factors, including the fact that the suppliers are frequently in a position to create the demand, are involved. The political feasibility of a change in the tax and health delivery system is another question. But a package of reforms, with a broad set of trade-offs, might be feasible. This suggests the nature of institutional diagnosis and prescription.

Final Comments

The discussion of the problems in articulating preferences in the political system and the implications of the influence system may be taken as an argument against regulation. It is not. There is no alternative to regulation. The relevant questions have to do with designing political and economic institutions which im-

prove the capacity to identify information about preferences and the production opportunity sets. There is no avoiding the fact of conflicts of interests and political and economic power. It may be an act of faith that a better understanding of the system will contribute to improved performance, however that is defined politically, but for scientists that faith is necessary.

It should not be assumed that because the regulatory system is the result of influence that a just society is impossible. Participants are members of communities. They have all been socialized. In the end, ideology—the basic accepted beliefs about the good society—affects the decisions of most of the participants. The political economy produces the belief system and is subsequently controlled by it. If we are to understand the regulatory system we must understand the evolution of the prevailing ideology and attend to the problem of shaping the ideology which will control our future.

References

Bartlett, Randall. *Economic Foundations of Political Power*. New York: Macmillan Co., 1973.

Lipset, S. M. and W. Schneider. "The Public View of Regulation." *Public Opinion*, Jan./Feb. (1979), pp. 6–13.

Martin, M. V. and R. P. Dahl. *Social Costs of Regulating Railroad Grain Rates in the Upper Midwest*. University of Minnesota Agr. Exp. Sta. Tech. Bull. 319, 1979.

Posner, Richard A. "Taxation by Regulation." *Bell J. Econ.* 2 (1971), pp. 22–50.

Schmid, A. Allan. *Property, Power and Public Choice*. New York: Praeger, 1978.

Stigler, G. "The Theory of Economic Regulation." *Bell J. Econ.* 2 (1971), pp. 3–21.

U.S. Congress, Senate, Committee on Governmental Affairs. *Framework for Regulations. Study on Federal Regulation*, vol. VI. Document 96–13, 95th Cong., 2nd sess., Dec. 1978.

Wellford, H. *Sowing the Wind*. New York: Bantam Books, 1973.

Economic Analysis of the Regulation of Agriculture

Bruce L. Gardner

This paper consists of two unequal parts. The first treats the normative economics of regulation—why and how it ought to be done. The second part is about positive economics—how to analyze the consequences of regulatory alternatives. The bulk of the paper concerns positive economics, but a brief recap of a standard normative framework for regulation is an essential preliminary.

The Rationale for Regulation

Theoretical welfare economics has not succeeded in giving scientific status to value judgements, but it does provide results that help us think reasonably about issues in political economy in general and about regulatory activities in particular. It helps first of all by insisting that governmental activity must be justified in terms of making us collectively better off. It is not enough that somebody be made better off; in some meaningful sense, we must be made better off collectively. This view focuses attention on the community's welfare, a concept which may not be precisely definable, much less measurable, but which is nonetheless a useful focal point for thinking about the justification of regulation.

An elementary but helpful way to think about the reasons for regulation is provided in Figure 1. It depicts some socially valued activity—for instance, the production and consumption of beef. The figure represents two general realities. First, successive increments in the quantity of the good or service, Q_i, yield reduced incremental social benefits. Thus, the function labelled MSB_i (marginal social benefits) has a negative slope. The reason is that when small quantities are available, they can be used to satisfy the most urgent and important uses, while successive increments are used to satisfy less urgent and important uses. Second, successive increments in Q_i require increased incremental cost. Thus, the function labelled MSC_i (marginal social cost) has a positive slope. The reason is that when increased quantities of resources are used to produce Q_i, the marginal value of other goods and services that must be sacrificed to produce an additional unit of Q_i increases.

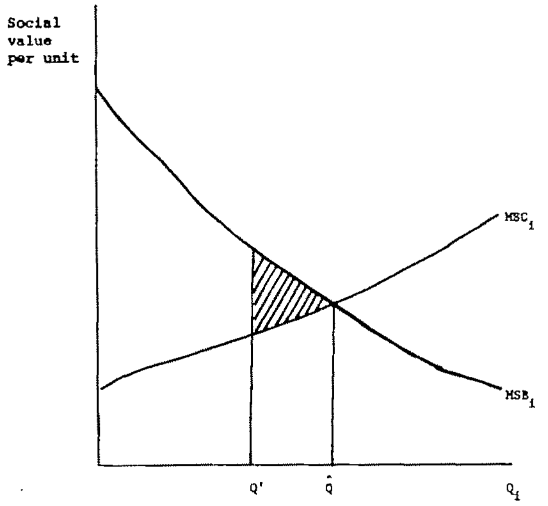
The community is made best off when its resources are allocated to activities such that $MSB_i = MSC_i$ for all i, e.g., at $\hat{Q}$ in Figure 1. While the diagram is a partial equilibrium depiction of the Q_i activity, the identification of MSC_i as opportunity cost implies the many-activity optimality condition that the community's resources should be allocated such that a given value of resources yield the same MSB in all activities. If the economy were operating at some suboptimal level such as Q', a move to $\hat{Q}$ would generate additional benefits equal to the area under MSB_i and additional costs equal to the area under MSC_i. Therefore, there is a net social gain which can be quantified as the roughly triangular hatched area. The gain can be thought of as the welfare loss resulting from being at Q' rather than $\hat{Q}$.

In the context of a market economy, the question is where the market-determined activity level Q_i is located in relation to $\hat{Q}$. One can imagine an ideal case in which: (*a*) the market price of a product is identical with its marginal social value; (*b*) the marginal private costs are identical to the marginal social costs; (*c*) there exists a market demand function identical to MSB_i as a function of Q_i; (*d*) there exists a market supply function identical to MSC_i as a function of Q_i; and (*e*) the market institutions generate equilibrium at $\hat{Q}$. There can easily be divergence at any of these points. Let me give an example. The social value of stored grain—its potential value in time of shortage—differs from its market value if the social value includes the desires of poor people abroad who could not afford the high prices in time of shortage. The market demand function differs from the marginal social benefit function if the private stockpilers' discount rate differs from the relevant social dis-

---

Bruce L. Gardner is a professor of agricultural economics at Texas A&M University. This paper has been approved as technical article TA-15168 of the Texas Agricultural Experiment Station.

Figure 1. Optimal and Suboptimal Activity Levels.



count rate. The private costs of producing grain differ from the social costs if external costs occur, e.g., fertilizer runoff polluting streams. Even if private and social costs are equal, the market supply curve yielding output $\hat{Q}$ will not be observed if monopoly power exists. And, even if all else is in order, the market may not operate efficiently to find position $\hat{Q}$ because of irrationality, imperfect information, or inflexibility under rapid change.

The justification for regulation of markets is to move toward positions like $\hat{Q}$ from positions like Q' generated in unregulated markets. This view suggests defining regulation as governmental intervention in markets in search of $\hat{Q}$. However, the definition should not turn on the goal of the intervention. Any systematic direction or management of markets in the food and fiber sector by government can be considered "regulation of agriculture," regardless of the goal sought. This definition is not so broad as to include all governmental activity that has an economic impact on agriculture. It excludes general revenue-raising or expenditure measures (income taxes or welfare programs), and it excludes the legal background that establishes property rights, defines fraud and otherwise specifies fair dealing. Thus, the term "unregulated market" does not refer to a fictional state of anarchy, but simply to the absence of direct intervention in market pricing, production, consumption, or trade.

Regulation of Agriculture

Weidenbaum (pp. 6–8) lists thirty-seven major expansions of U.S. federal regulatory activities under congressional mandate between 1962 and 1974. Of these, twelve have significant implications for farming or markets for agricultural products, and five of the twelve are aimed exclusively or primarily at agricultural products (Cigarettes and Health Act, 1965; Fair Packaging and Labeling Act, 1966; Flammable Fabrics Act, 1967; Wholesome Meat Act, 1967; Wholesome Poultry Products Act, 1968; Public Health Smoking Act, 1970). Weidenbaum's list excludes such pertinent legislation as the "Delaney Amendment" (21 U.S.C. 348(C) (A)) and other legal restraints on cancer-causing agents in food, the successive extensions of the Fair Labor Standards Act to more farmers, the act establishing the Commodity Futures Trading Commission, the act establishing the Federal Grain Inspection Service, and the commodity programs authorized and put into place under the Food and Agriculture Act of 1977 and the Emergency Agriculture Assistance Act of 1978, as well as other regulatory activities to be mentioned below. Thus, farmers' perception that their regulatory environment is becoming congested, absolutely and relative to other sectors, appears justified.

Moreover, there is evidence that some general regulatory activities have larger effects, with greater cost relative to benefits, on agriculture as compared to other sectors. For example, Peskin and Peskin (p. 85) estimate that while agriculture (Standard Industrialization Code 01) accounts for about \$200 million annually or 1% of U.S. air pollution damages, costs to meet the Environmental Protection Agency (EPA) standards in agriculture would be \$1.1 billion annually (in 1970 dollars), 5% of U.S. total costs to meet EPA standards.

The main justification for regulation of agriculture seems to be that welfare losses may be reduced in the following ways: (*a*) fostering competition or otherwise improving the functioning of markets; (*b*) equating marginal social benefits to marginal social costs when externalities (on either the demand or supply side) exist; and (*c*) redistributing wealth efficiently.

Regulation can be aimed to foster competition by intervening to increase the number of firms or to dictate certain courses of action—

actions such as those currently being required of breakfast cereal manufacturers and retail grocery stores in concentrated markets. Another example is the concern that the performance of the livestock/wholesale meat markets has been hampered by the practice of formula pricing based on the National Provisioner's "yellow sheet."

Regulation intended to improve resource allocation in the presence of externalities justifies a broad range of activities. Fertilizer runoff, by-products of feedlots, and wind-blown pesticides are obvious externalities suggesting an environmental regulatory effort. In addition, some agricultural activities provide external *benefits,* and these may justify regulation to preserve open space, land-use planning, and so forth. In addition, externality arguments have been extended to worker-safety and food-safety issues on the grounds that if Mr. A becomes ill, the rest of us pay more taxes for public health purposes. Therefore, regulation of Mr. A's workplace, diet, and so forth to promote and protect his good health is justified.[1]

The third listed reason for regulation—redistributing wealth efficiently—gets less attention in most discussions. It is probably true that promoting competitive market pricing and dealing with externalities are the two most prominent general regulatory fields of action that can potentially move the nation's agricultural activities toward a position like $\hat{Q}$ in Figure 1. Yet, and here I am driven into the impressionistic realm of personal experience, these considerations leave out a great deal of what regulation is all about. What regulation is all about is a matter of what the regulators are, in fact, doing and why. In my own experience, which was as the staff member of the Council of Economic Advisers (CEA) covering food and agriculture during 1975–1977, most issues that came up were regulatory issues. However, people who were making or recommending decisions on these matters rarely did so as part of an attempt to manage markets so as to minimize areas of triangular welfare losses as shown in Figure 1.

What are the real issues, then? It seems so evident as to be a truism that the definition implicit in the title of Harold Lasswell's book is right: *Politics: Who Gets What, When, How.* The real issue in the economics of regulation as practiced is, how (or by how much) shall the economic well-being of one worthy group of citizens be reduced in order to benefit another (presumably even more worthy) group of citizens. It might be thought that this issue has nothing to do with $\hat{Q}$ or welfare losses, but this idea is incorrect on two counts. First, while economists often speak of an efficiency/equity trade off or words to similar effect, one can think of the achievement of fairness or justice of market outcomes as part of what determines $\hat{Q}$. Thinking along these lines is encouraged by philosophers like Rawls who have made it their business to analyze concepts like justice in a nonsentimental and rigorous way. Second, and more practically relevant, putting redistributional measures into effect thereby places the economy at a point away from $\hat{Q}$. The regulatory issue is how to manage redistribution in such a way as to minimize the welfare costs resulting from it.

Example: The Jones Act (46 U.S.C. 883) requires, basically, that goods shipped from one point on the coast of the United States to another point on the coast of the United States must be transported on American ships. However, the Act permits exceptions in the case of national emergency or the overriding interest of the country, if the President officially so determines. My reading of the Jones Act is that Congress decided to transfer wealth from people who use shipping services to our ocean shipping industry by means of limiting foreign competition, unless the social costs of doing so became too great. Now, during the time I was at the CEA certain lack of nitrogen fertilizer occurred in the Pacific Northwest, and it was found profitable to ship the product from Alaska. But it was said that no appropriate American shipping was available, while a foreign-owned barge that could perform the required services was available. Regulation involved the preparation of a report on the issues and a recommendation as to whether the President should find danger to the U.S. economy sufficient to permit this foreign barge to ply its trade. I am glad to report that the governmental resources necessary to provide a full legal and economic analysis of this issue that would be fully sensitive to spirit and letter of the Jones Act was not undertaken, yet the barge was permitted to sail anyway. A number of lessons could be suggested from a fuller development of this regulatory episode, none of them encouraging optimism about the pros-

[1] This externality can also be expressed in reciprocal terms as a social cost of public provision of health insurance, which raises the question of whether it is socially preferable to move toward $\hat{Q}$ by regulation of health or by regulation of health insurance.

pects of achieving $\hat{Q}$ through the regulatory route. The point here, however, is that regulation can move us toward $\hat{Q}$ not only by undoing market failure but also by undoing legislative failure.

Analyzing the Consequences of Regulation

The analytical and informational expertise required for intelligent choice in regulatory matters is truly formidable. The necessary preliminary steps of quantifying social benefits, social costs, and even units of measurement for the output of the good or service in question, involve great difficulties in practice. The actual determination of $\hat{Q}$ for practical problems is more difficult still.[2]

Consider an example in which the economic analysis necessary for socially optimal regulation might be attainable without too many problems—the optimal carryover storage of grain. Stockpiling is a justifiable regulatory issue because of externalities and possible ill-functioning of markets that suggest governmental intervention to attain $\hat{Q}$ in this activity. There exists a good deal of econometric analysis that is pertinent to optimal stockpiling. But, even so, one finds sufficient uncertainty about future trends in supply and demand, the elasticities of supply and demand, and the costs of storage that a substantial range of recommendations about optimal stock levels results. $\hat{Q}$ cannot be estimated with precision. Moreover, the externalities that the private trade ignores are extremely difficult to quantify. There is even disagreement on exactly what kinds of things these externalities are.

The difficulties faced in determining $\hat{Q}$ are no less, and indeed are probably more formidable, in other areas of regulation of agriculture. In fact, the difficulties are so great as to give Figure 1 an appearance of pure pie-in-the-sky, as far as any hope of actually attaining Q is concerned.

Nonetheless, in regulatory decision making economists can be of real assistance in promoting rational social choice. First of all, we can search for evidence as to the costs imposed by unregulated markets as compared to ideally managed markets. Second, we can attempt to assess the consequences of alternative regulatory proposals. The remainder of this paper is devoted to discussion of how best agricultural economists can provide these useful services.

Estimating Effects on Producers

Two fine examples of positive economic analysis of regulatory activity are the USDA's study of the prohibition of subtherapeutic uses of animal drugs and the National Brucellosis Technical Commission's study of alternative schemes for brucellosis eradication. Both show what costly and time-consuming effort is needed to bring our best analytical tools to bear on issues of benefits and costs. Two problems exist with these studies and the problems are even more serious with less ambitious studies of benefits and costs. First, even our best econometrics often leaves much to be desired, especially when results involving cross-commodity effects and transitions from farm to retail are involved. Quantitative estimates often appear more solidly based than they really are. Second, econometric models tell us especially little about the issues policy makers are most interested in—who gains and who loses, and how much.

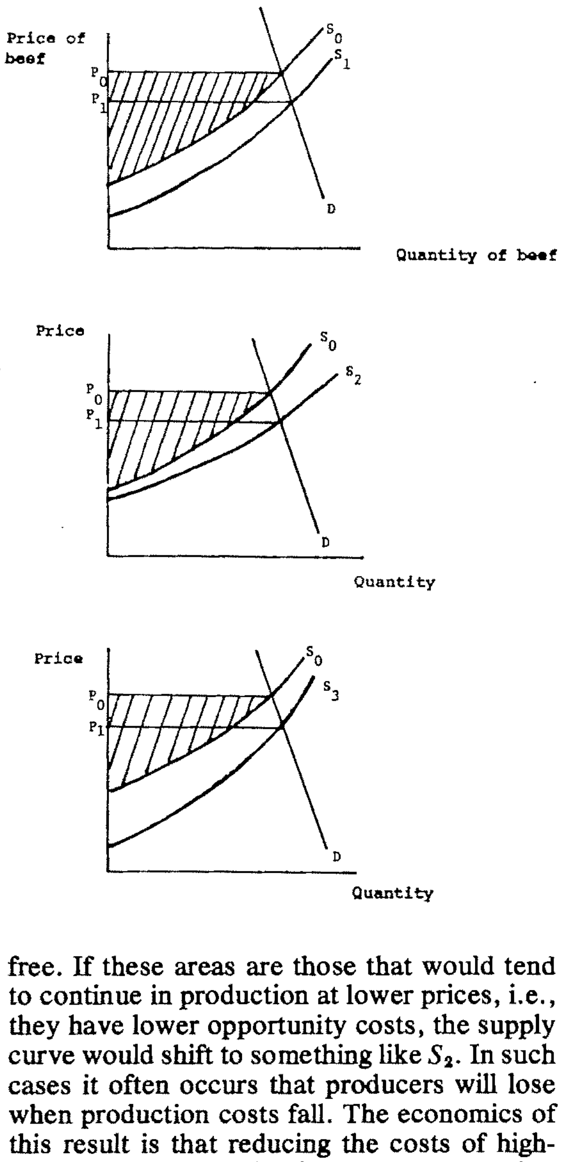
On the consumer side, the measurement of gains or losses is relatively straightforward. Lower prices reduce expenditures and increase consumers' surplus, and both can be estimated. On the producer side, however, the situation is more complicated. The reason is that regulation of production practices does not shift supply functions in easily specified ways, while the measurement of producer gains (producers' surplus or rents) depends on what happens along the whole length of the supply function, not just at the margin.

Figure 2 shows three possibilities in the context of brucellosis eradication. First, suppose that the supply function shifts downward by a constant amount from S_0 to S_1, i.e., production costs fall by a constant amount. Producers' rents then must increase, since output increases, and the fall in price is necessarily less than the vertical shift in supply (unless demand is perfectly inelastic or supply is perfectly elastic). Note that producers' rents increase even though total revenue will decrease if demand is inelastic.

A second possibility is that production costs are reduced to yield the same market price as S_1 does, but intramarginal production is not so greatly affected. Nonuniform effects are likely for brucellosis eradication because some areas of the United States are already brucellosis-

[2] Some potentially workable ideas for governmental management of analytically intractable regulatory problems are outlined in Bosworth's paper at this conference.

Figure 2. Alternatives for a Shifting Supply Function.



free. If these areas are those that would tend to continue in production at lower prices, i.e., they have lower opportunity costs, the supply curve would shift to something like S_2. In such cases it often occurs that producers will lose when production costs fall. The economics of this result is that reducing the costs of high-cost marginal production creates tougher competition for low-cost intramarginal production. For example, if we make it cheaper to grow corn in Texas, this makes Corn Belt producers worse off.

The third possibility is the converse of the second. A result of this kind is shown as S_3 in Figure 2. Price falls the same amount as under the S_0 to S_1 shift, but producers' rents increase even more than they did under the S_0 to S_1 shift.

Unfortunately, the standard econometric models and estimating procedures do not permit discrimination among these three alternatives. It is possible to compare arithmetic shifts of supply equation intercepts (the first case) with percentage shifts via logarithmic specification or changing-parameter models (a particular sort of S_0 to S_2 shift). In general, however, the analysis of producer benefits or costs from regulatory measures requires a more detailed structural investigation of the supply function than is typically undertaken for purposes of price forecasting or other standard uses of econometric models. For an example of empirical work with attention to the structure of supply shifts, see Scobie and Posada T.

Choosing Among Alternative Analytical Possibilities

In stating the results of investigations into the consequences of regulation—for example, in informing regulatory authorities about estimated benefit-cost ratios of program alternatives—consideration should be given to the ways in which regulators will decide what to believe. Consider these two propositions: it is altogether too easy to convince people of what they expected to hear anyway; and the researcher's ability to gain credibility as an "expert" is perhaps even more important than the evidence actually adduced.

For example, the U.S. government is perpetually considering the pros and cons of allowing more foreign sugar into the U.S. market. We have some econometrics to indicate price effects, consumer losses, and producer gains. But these estimates are limited by the relevance of the elasticity estimates and the models they come from. It is tempting to say that more sugar imports lower price in the short run as our model shows. However, in the long run maybe the shrinkage of U.S. sugar production would lead to higher prices. This is of course a possibility but there does not seem to be any evidence on the matter. Nonetheless, if we are not careful, we find ourselves saying that free trade in sugar is just as likely to make consumers worse off as better off. It is not surprising that industry representatives will accept such results, but it is somewhat dismaying how readily disinterested regulators can be induced to accept dubious results. This does suggest the importance of taking into account the process by which administrators reach their views on analytically uncertain questions, which is what most quantitative assessments of benefits and costs of regulatory options are.

Role of Conceptual Advances

In some regulatory issues, conceptual advances are perhaps at least as important as econometrics. Indeed, my own belief and experience is that significant progress in regulatory matters could be made by a serious and consistent recognition that demand curves slope downward and supply curves slope upward in both the short and long run.

Conceptual advances beyond this are rare. An outstanding example is available in the regulation of agriculture: namely, the analysis of classified pricing under marketing orders developed in Kessel; Kwoka; Ippolito and Masson; and Buxton. What they collectively provide is basically a model of a price-discriminating cartel with free entry. To review the basic ideas—classified pricing provides a way to sell a given quantity at a higher average (blend) price; namely, set a price differential which charges more for uses relatively inelastic in demand. A common reaction to the assertion that price enhancement results from classified pricing is that, after all, supply is not controlled, so production will tend to expand until expectations of profit are eliminated.[3] The service of the literature mentioned above is to show what the resulting zero-profit equilibrium looks like. The general result is that the higher blend price induces more than the unregulated market's output; and that, while there are zero profits, producers' rents are higher at the higher price. This model is basically similar to a Chamberlinian monopolistic competition model—a model which also can be used to depict a cartel with free entry. With not much further development such models could throw light on the economics of the flow-to-market regulations used by many associations of producers under marketing orders. The empirical implementation of such models will require sensitive and detailed work, but should eventually provide the appropriate positive economics for public decisions in this area.

Other marketing issues need a better conceptual basis for rational regulatory action. With respect to "yellow sheet" pricing of meat, there is need for a better theoretical framework for assessing the likely gains and costs of abolishing or restricting formula pricing. The issue here is not so much competitiveness per se, but the adaptability and efficiency of market institutions. Returning (it seems inevitable) to milk marketing, Earl Butz as Secretary of Agriculture had confidence in markets, but even he justified classified pricing of milk under federal market orders on the grounds that unregulated markets could not properly handle the geographical distribution and pricing of a randomly produced perishable commodity that can also be processed. Is there a coherent conceptual framework for this result?

Analyzing Intervention Approaches

In addition to measuring benefits and costs, economic research on environmental issues can explore fruitfully private market mechanisms for internalizing externalities and the consequences of alternative forms of intervention. There has been interesting work on the reciprocal external benefits resulting from the interdependence of beekeeping and orchard or other flowering crop enterprises (Cheung, Johnson). On the issue of alternative forms of intervention, one important area for research is the pros and cons of direct regulation versus performance standards. Should the government attempt to specify particular production practices or safety equipment to protect farm workers health and safety, or should there instead be penalties imposed for accidents or negligence with farmers left free to choose specific practices?

Another area of choice is who is to pay penalties or receive subsidies to best achieve $\hat{Q}$ when externalities exist; for example, the bill for environmental cleanup or damage prevention. The alternatives usually considered are taxes or other charges against polluters versus subsidy of environmentally desired procedures. To date there seems to have been a greater reluctance to impose charges or other costly adjustments on farmers than on industrial polluters. And when one rural enterprise imposes external costs upon another, there is a marked tendency not to impose regulatory costs on either party but to compensate environmental losers at the expense of the general taxpayer. The best example is the beekeeper indemnity program. The use of certain pesticides in crop production or orchards

[3] The USDA reaction to charges of price enhancement by cooperatives under marketing orders has typically been along the following lines: "A vague or inaccurate notion of what agricultural cooperatives do and of powers they have, and a lack of understanding of the complexity of the agricultural marketing system in this country and the uncertainty of agricultural production as a way of life everywhere in the world is the source from which most criticism stems" (Smith, pp. 8–9).

sometimes unintentionally kills honeybees. The traditional mechanism for handling such an externality would have been to establish liability on either the pesticide user or the beekeeper through court cases. This approach would be analogous to the approach to dealing with damages caused by wandering cattle, as discussed by Coase. But the beekeeper indemnity program effectively settles liability upon the general taxpayer, since injured beekeepers are paid for damages out of the U.S. Treasury, not from assessments on producers. One would suspect that this approach would not lead to socially optimal practices in either pesticide use or beekeeping.

Assessing Regulatory Choices

The economic behavior of regulatory authorities should be better understood in order to assess the chances of attaining $\hat{Q}$ through government. Economic analysis of legislative decisions is a time-honored field of study going back at least to Beard. The discussion of the Jones Act above suggested that legislation to redistribute wealth creates divergences from optimality that regulation in the executive branch can correct. However, maybe the executive and the independent regulatory agencies cannot be trusted to move us toward $\hat{Q}$. Stigler is representative of a school of thought that sees real problems arising from the interests and incentives of regulatory agencies as related to the interests of the industry regulated. My own view is that this emphasis in the "new theory of regulation" is misplaced when applied to the more recent areas of regulation in agriculture (although it is well placed as applied to commodity programs and marketing orders). More pertinent in the newer areas is the traditional complaint that the regulators too often literally do not know what they are doing.

Economists can make useful contributions to the topic of how to regulate when you do not know what you are doing. In grain stockpiling, for example, one can explore the sensitivity of $\hat{Q}$ to the range of uncertainty about the unknown parameters which determine optimal storage. And, regulatory steps which do not yield extremely undesirable results can be suggested even when the assumptions on which they are based turn out to be wrong. Such policies may be called "robust." In addition, it is possible to learn from the outcomes of regulatory activity. For example, the knowledge base accumulated from past acreage control programs is a real help in avoiding errors in proposed price support schemes. An interesting treatment of optimal learning is provided in Rausser.

Problems which are more difficult still arise when the conceptual apparatus of Figure 1 is of uncertain relevance. Consider the idea of regulation of diet or nutritional information in pursuit of better health in the population. Regulation here involves a determination that the regulatory authority has knowledge that consumers, or a substantial subset of them, do not. This is said to justify taking measures to induce people to behave differently in their market choices than they otherwise would have. The definition of $\hat{Q}$ in such circumstances involves *MSB*'s based on something other than an aggregation of individual utility functions, which creates real difficulties in saying what $\hat{Q}$ means. Similar difficulties arise when market participants try to influence one another's preferences and actions. Nonetheless, in a case like regulation intended to further the Senate Nutrition Committee's dietary goals, while the effects on producers of beef, sugar, and so on, are a matter of concern, the welfare effects on the consumer side are even more problematical.

Similar conceptual problems arise with reference to the "structure" of farming, which is appearing on the horizon as a major regulatory target. The criteria by which one judges whether one attains $\hat{Q}$ more satisfactorily with one million or three million farms are not readily available from the type of welfare economics that lies behind Figure 1.

Regulating Uncertain Markets

One of the special characteristics of regulation in agriculture is that it is often concerned with managing markets under uncertainty. Regulation here involves difficult valuational problems in assessing benefits and costs, and in forecasting the private market response to regulatory intervention. Areas in which research has been undertaken include: management of grain stockpiling, programs to help producers cope with production uncertainty, regulation in the areas of credit and insurance, governmental regulation of private price-discovery institutions (e.g. futures markets), and provision of market information and forecasts.

The issues in regulation under uncertainty

bring out a fact that becomes ever more apparent as one considers the problems discussed in this section: good regulatory research is on the frontiers of agricultural economics. It is not that the research has to be esoteric or requires a Ph.D. in mathematics, but that we have to go beyond our standard tools of commodity market analysis. By this, I do not mean that we ought to be throwing our textbooks in the trash can. But we do have to be reaching out for new sources of information and new techniques of analysis. It is noteworthy that much of the recent work that has promise for improving our ability to analyze regulatory alternatives in agriculture comes from outside agricultural economics. For example, in the area of regulation under uncertainty the *Bell Journal of Economics* has recently published three papers that may be extremely useful to agricultural economists (Bradford and Kelejian; Nichols and Zeckhauser; Yohe). Each of these papers treats agricultural market analysis, albeit sometimes only in passing, from a point of view arising from developments in general economics which strike one as having great potential for more detailed application. While keeping up with developments in general economics involves major investments of time and effort, the payoff in advancing the analysis of agricultural regulation should more than justify the costs.

A final point that pertains to all the research issues discussed is that the applied nature of the research is a key characteristic. The fundamental theoretical issues—for example, the meaning and measurement of consumer's surplus, or general theoretical or ideological discussion of the proper role of the State—are ignored. This omission reflects my own prejudice that the comparative advantage of agricultural economists does not lie in the study of these general topics.

Concluding Remarks

It is in principle possible to identify socially optimal activity levels like $\hat{Q}$ in Figure 1, but it is often not possible in practice. And while it may be expected on a priori grounds that unregulated markets will fail to attain $\hat{Q}$, it is extremely difficult to judge how to attain $\hat{Q}$ through regulation. This paper has discussed how economic analysis can contribute to improved regulation of agriculture. There are several respects in which regulatory research differs from the applied econometrics usually undertaken by agricultural economists: (*a*) More detailed knowledge of structural relationships is necessary to estimate the distribution of gains and losses from market intervention than is necessary for price forecasting; (*b*) Concentration on hypothesis-testing based on rejection or failure to reject a null hypothesis often does not help in regulatory matters where the issue is choice among two or more regulatory proposals; (*c*) The audience for regulatory research is often not composed of professional economists familiar with agriculture. Communication of results and the arts of persuasion play an even larger role than usual. One needs to avoid jargon like a plague and base results on self-contained reasoning, not on unstated theories or doubtful assumptions whose failure would negate the conclusions reached.

The discussion of the preceding and related issues in this paper has been more sketchy and impressionistic than one might prefer. This reflects not only the limitations of the author but also the state of flux in the subject. It is perhaps the most exciting and promising area of research in agricultural economics today, because there is a strong demand for economic analysis in the area and because a substantial supply of analytical techniques that hold promise have not yet been systematically applied. I would go so far as to say that in the coming years the standard core of material that goes under the label of agricultural economics will be substantially changed, and that economic research on regulation and political economy in general will be at the center of this change.

References

Beard, C. *The Economic Basis of Politics*. New York: Vintage Books, 1957.

Bradford, D. R., and H. H. Kelejian. "The Value of Crop Forecasting with Bayesian Speculators." *Bell J. Econ.* 9(1978):123–44.

Buxton, B. M. "Welfare Implications of Alternative Classified Pricing Policies for Milk." *Amer. J. Agr. Econ.* 59(1977):525–529.

Cheung, S. "The Fable of the Bees." *J. Law and Econ.* 16(1973):21–34.

Coase, R. A. "The Problem of Social Cost." *J. Law and Econ.* 3(1960):1–44.

Ippolito, R. A., and R. T. Masson. "The Social Cost of Government Regulation of Milk." *J. Law and Econ.* 21(1978):33–66.

Johnson, D. B. "Meade, Bees, and Externalities." *J. Law and Econ.* 16(1973):35–52.

The Economics of Regulation: A Critique

Jane Campana

Not since the 1930s have we been involved so intensively with the manner in which regulation affects the economy; not since the New Deal have we had occasion to re-examine the scope and complexity of regulation as it affects our economic activities on every level.

I cannot begin to pinpoint the cause of the current concern about pervasive government regulation. Perhaps many of the regulatory institutions themselves have been rendered obsolete by changed economic conditions. Perhaps the social acceptance of economic regulation has spurred firms in specialized sectors of the economy to compete not in the actual marketplace, but in the regulatory marketplace, and government in general has been only too happy to respond to their interests. Certainly, during the last decade, recognition of the need for new social goals such as a cleaner environment, avoidance of an energy crisis, safer foods, drugs, and working conditions has left in its statutory wake a plethora of regulations that impinge on every kind of economic activity.

In any event, the public's recognition of the scope and complexity of economic regulation is growing daily. And common to both the public at large and to the "regulatory community" is the perception that the lawyers are responsible.

No self-respecting lawyer would decline the chance to assume major responsibility for the mechanics of a regulatory scheme, although he or she might decline to criticize some of the particulars on the grounds of professional courtesy. It is true that, in many areas of economic regulation, the policy behind the regulation, as well as the manner in which it is applied and its subsequent tests of validity in the courts, has been largely controlled by lawyers. Whether we should perceive this control as bringing a flow of benefits to lawyers to the detriment of society in general is a question that could be endlessly debated. Personally, I would not trust an economist to do that analysis.

However, economists are beginning to have an expanded role in current regulation. This does not mean just analyzing the nuances of established regulatory schemes, but also determining whether a regulation is necessary or beneficial in the first place. This is as it should be. Economists have a particular advantage in taking a direct role in the regulatory process since the task is extremely technical and becomes more so each year. Moreover, the economist's role is not and should not be limited either to cost-benefit analysis or to forecasting the many effects of a particular regulatory issue; rather, economists should be prepared to make substantial contributions to the ultimate issues of public policy.

As a lawyer who has had substantial professional contact with economists, I would not deprecate the importance of the increased role of economists either in assisting the regulatory process in a technical sense or in the formation of basic policy. In the former role, there is no question that, as Alfred Kahn has observed, lawyers who do not seek the cooperation of economists cannot understand what their opponents' witnesses are saying (p. 15). In the latter role, bearing in mind that value judgments are implicit in applied economic theory, there is no reason why economists are not at least as qualified to render judgment on issues of public policy as are lawyers, politicians, and other social scientists. Besides, most lawyers generously would make room for economists to share their role as the bearers of bad news.

The Role of the Economist versus the Role of the Lawyer

However, as a lawyer by training and an economist by marriage, I do have some observations which I would like to share with you today on the respective roles of lawyers and economists in the regulatory process.

For the purpose of a tidy analysis of those roles, it is tempting to try to distinguish between those situations in which economic re-

---

Jane Campana is an attorney, Office of the General Counsel, Council on Wage and Price Stability, Washington, D.C.

search is used to provide technical expertise, and those situations, increasingly frequent, where economic research and principles play a major role in policy formation. The fact that such a distinction cannot be drawn easily reveals two fundamentally different views of the economics of regulation; first, the lawyer's perspective of regulation as a process. And, second, the economist's perspective of all regulation as having economic consequences, if not economic purposes.

Lawyers are indoctrinated in process: its origins, its use, and somewhat peripherally, its ends. For the origins of the political process, a lawyer would look to the Constitution whose relevant interpretations are mostly in the realm of procedure.

The concept that economic regulation does not violate the due process clause of the Constitution, as long as it is properly delegated and reasonably related to a legitimate legislative purpose, is so firmly embedded in the constitutional law of the last seventy years that it needs no discussion here. Suffice it to say that a lawyer's view of regulation as a product of the political process is logistically grounded in constitutional law and that constitutional law provides no guidance about the substance of economic regulation. It dictates only the procedural safeguards without which that regulation would be found deficient on grounds of procedural due process.

Procedurally, regulation in the traditional sense is derived from statutes enacted by Congress. However, as anyone who has observed the workings of Washington can readily tell, regulation is a rather complex process in which particular legislative provisions are often not the results strictly of congressional initiative but are instead responses to the initiatives of regulated industries, public interest lobbies, agencies created to handle already-existing regulatory schemes, or the executive or judicial branches, all of whom may in turn derive their initiative from any of the others.

The political constraints on the use of economic research are part and parcel of the origins of economic regulation. Since that subject could occupy the entire career of a political scientist, I will not attempt to deal with it here.

However, it is obvious that the process of creating economic regulation is one in which economic principles can be and increasingly are applied freely. It is at this point that the economist's perception of all regulation as having economic consequences, if not economic motivation, can come into play most freely.

Until a regulatory scheme is enacted, its motives and its probable consequences can and should be closely scrutinized from every angle. And there is no reason for this process to stop once the regulation is enacted. The results of economic research can be applied fruitfully when legislation is designed neither to control a market nor to address itself directly to any particular economic goal, but to achieve instead a result whose economic consequences are unlikely to be perceived. I am speaking of legislation designed to achieve social goals, like clean air or safe food and drugs; to eliminate inequities, like civil rights legislation, and to set minimum standards, like that which regulates professional groups.

The Economist's Role in Developing Legislation

Using economic analysis in creating these types of legislation often has been ignored. Instead, this analysis has been treated either as an interesting but unnecessary perspective, or flatly rejected in favor of advancing an overriding legislative purpose. Even now, the procedural bias of lawyers and legislators is apparent and can condition or defeat the use of economic analysis.

Let us look first at the role of economic analysis in developing legislation to set minimum standards for professional services. One such statute, which I have had the bad luck to encounter, is a state statute requiring barbers to be licensed. I am sure this statute was enacted largely to enhance the status of barbers in the state. Legislators would claim that the purpose was to protect people from having their hair butchered by incompetents or touched by felons. Economists would say that the statute's purpose was to restrict entry to the profession and thus enhance the incomes of those already in it.

The statute says that barbers must receive licenses before they can practice their art, and that in applying for the license they must state that they have never been convicted of a felony. I am sure that no study of the supply of barbers in the state or the demand for their services was done when this legislation was enacted, nor, to my knowledge, has one been done since. Nevertheless, the state legislature, in its infinite wisdom, several years later decided that the state did not have enough

trained barbers and there were a lot of inmates in the state prison who should be taught a useful trade. Given this woeful clash between legislation restricting the supply of barbers and legislation designed to expand the supply of barbers, the inevitable happened.

My client was, of course, a convicted felon who had been trained as a barber in the state prison, but was unable to receive a license from the Board of Barbers. In this particular instance, as in so many others, procedure provided the solution. The Board of Barbers, for the first time in its history, convened to hear an appeal and, even though the rejected applicant originally got his felony conviction for robbing the house of the Chairman of the Board, the Board ultimately granted his license. The point of this story is that the legislature never understood the economic consequences of the law's enactment; legislatures routinely pass laws designed to set minimum standards for professional and other groups and rectify what they perceive to be inequities without perceiving that there are economic consequences.

Of course, economic theory also can be used to justify legislation enacted to correct inequities. For example, courts which were asked to decide whether the government could extend the mandate of the Civil Rights Act through the use of procurement power relied heavily on a purely economic argument. That argument was that, since the effect of applying the Civil Rights Act to government procurement would be to expand the number of qualified applicants in the labor market, such an application would promote economy and efficiency in government. This was not the stated purpose of the Civil Rights Act nor of the Executive Order that applied it to government procurement, but research elaborating on its economic effects was instrumental in the subsequent tests of its validity.

The use of economic research in legislation primarily designed to further social goals, particularly environmental goals, is currently an area of great concern. It is in this area that a purely procedural orientation interacts most strongly with the perception that economic consequences inevitably result both from the passage of such legislation and its subsequent implementation through agency regulations.

The first battleground is the creation of the legislation itself. In recent years Congress has exhibited two conflicting tendencies in enacting legislation, both of which have many implications for the application of economic research. On one hand, Congress has made sweeping policy assertions with little guidance to the agencies created to carry out the mandate about the actual application of the policies. Two examples of this kind of legislation are the National Environmental Policy Act and the Food Additives Amendment to the Food, Drug and Cosmetic Act. On the other hand, Congress more recently has enacted legislation which so minutely details the considerations to be applied by the agency interpreting the legislation that the agency is left with little or no discretion to introduce decisional elements, like cost-benefit analysis, which Congress may not have considered.

The effect of the failure or refusal to provide explicitly for the use of cost-benefit analysis in both congressional and regulatory decision making has been to emphasize the procedural elements of the decision-making process, sometimes at the expense of the factors on which the decision is based.

Through its own rules Congress is now providing economic impact analyses for each proposed piece of legislation. However, these analyses tend to be somewhat perfunctory and often serve to deflect the basic question of whether the legislation is even necessary or desirable in the first place.

The Economist's Role in Agency Rule Making

Nevertheless, once legislation delegating power to an agency to implement a congressional mandate has been passed, the question often becomes, not what factors can be considered in implementation, but at what point in the decision-making process economic considerations can be introduced, if at all.

It is useful at this point to reflect on the notion of procedural due process as the courts have applied it. As Justice Frankfurter has said, "The history of liberty has largely been the history of observance of procedural safeguards" (McNabb v. United States). The procedural safeguards applicable to administrative agencies are expressed both in the Administrative Procedures Act and in the Administrative Law decisions of the courts. I am sure that most of you are aware of the Administrative Procedures Act, which provides, among other things, that when agencies undertake regulatory action through rule making

they must first articulate the basis for such action and then respond to public comments about it.

Economic analysis of the proposed agency action assumes its greatest importance during the notice and comment period, and it is at this point in the process that the battles over the relative weight of economic criteria in environmental decision making are presently being waged. The agency decision must be made on the basis of the record, taking into account such factors as it is allowed to consider, as expressed by the statute or in agency policy.

If a decision departs substantially from agency policy, the agency can be shown not to have taken into consideration certain factors that it is required to consider; if a change in policy is not justified by a reasoned analysis indicating that prior policies and standards are being deliberately changed not casually ignored, then the decision is vulnerable to challenge in the courts on the grounds that it is both arbitrary and capricious and also an abuse of agency discretion.

The importance of a legislative mandate to consider the costs and benefits of regulatory decisions at this point in the decision-making process cannot be stated too strongly. Even narrowly drawn acts can usually be reconciled with sound economic positions. In the absence of a legislative mandate, when an act is silent on what factors must be considered, it can be argued that economic considerations can and should be taken into account.

The timing of the introduction of the results of economic research into the decision-making process can also be critical. Recent court decisions have suggested that in certain circumstances, the record upon which an agency decision is based must be fully open to public participation and comment. Studies introduced after the close of the public comment period, if used as the basis for an agency decision, may make the decision vulnerable to challenge in the courts on the grounds that the decision was not based on the record and that there was no opportunity to counter the information presented. No court has yet struck down an entire regulatory scheme solely because an economic research study presented to the agency after the close of the public comment period formed the basis for the agency decision. However, the issue has caused agencies to draw firm lines around the manner in which information is presented to them and to define explicitly the factors which constitute their decisions. Until the issue is fully litigated, the procedural boundaries will be even more narrowly drawn.

It is to be hoped that one side effect of these developments will be an improvement in the quality of economic research. As economic considerations play an increasingly important role in agency decisions, the research in which these considerations are expressed will become more important and be the subject of more public scrutiny.

This brings me to my final observation. So far I have talked about three kinds of regulation: regulation designed to set minimum standards, regulation designed to rectify inequities, and regulation whose purpose is to promote broadly-stated social goals. I have not yet mentioned regulation which is designed primarily to foster economic goals.

This area is, more than any other, the realm of the economist. The decision about whether or not to regulate is one founded on economic theory (albeit not without value judgments), and the fashioning of such regulation is dictated primarily by economic principles. However, the lawyer still plays a rôle.

The Lawyer's Role

A lawyer's perspective is necessary here for two reasons: first, to introduce and ensure the maintenance of those aspects of procedural due process that are common to all regulation and second, to translate economic concepts and regulations into words.

If the central feature of economic regulation per se is the influencing of behavior in the marketplace, then the central feature of the mechanics of any regulatory scheme, the notion of due process, is that much more important. Regulation which proscribes or constrains behavior should always be preceded by public notice and an opportunity to be heard. To the extent that advance notice would cause the very behavior that the economic regulation is trying to prevent, a conflict between the concept of due process and the purpose of the regulation is inevitable. How, for instance, can even a voluntary pay or price standard be announced to take effect prospectively, without causing anticipatory pay and price increases of the very sort that the standard is designed to discourage? And how, in general, can any comprehensive economic regulation be implemented without retroactive conse-

quences, rendering actions which people have already taken unprofitable, risky, or even illegal?

As Alfred Kahn has observed; ". . . in a society that profoundly respects the institution of private property, the initiative, operating control, and responsibility for economic performance continue, even under regulation, to rest primarily with private management. The role of the government remains essentially negative: setting maximum prices, supervising expenditures, specifying minimum standards (for products or services), in short, contravening the decisions of private persons only after the fact, only when their performance has been or would otherwise be obviously bad" (p. 18). In essence, the economist's desire for an efficient marketplace, for the preservation of freedom of choice in the marketplace, and for other economic goals can and often does conflict with the lawyer's desire for a fair and orderly process by which decisions are made and conflicts resolved.

The final point I would like to mention concerns the lawyers' role in translating economic concepts into economic regulations. There are some who have claimed that lawyers have never been very good at written English. However, it is also undoubtedly true, that words are the lawyer's stock in trade. A lawyer would rather face a page of fine print than a single algebraic formula. When it comes to the job of writing regulations, neither fine print nor algebraic formulae are entirely satisfactory. Even if a regulated industry can survive on the precise guidance that statistical tables, square root signs and other incantations can provide, in the final analysis economic regulation, its concepts, and the manner in which they are applied must be comprehensible to a judge and sometimes to a jury as well. Economic research, which forms the basis for decisions must be equally comprehensible, lest it be ignored by those unschooled in such things as the techniques of quantitative multivariate analysis.

In short, both professions come to the process of regulation armed with the respective jargon of their trades. It is the task of both professions, and it is not a small task, to demystify the theory and the application of economic regulation. While this partnership will not be without tension, it has every promise of being extremely fruitful.

References

Kahn, Alfred. *The Economics of Regulation*, vol. 1. New York: John Wiley and Sons, Inc., 1970.

McNabb v. United States, 318 U.S. 332, 347 (1943).

Regulation and Economic Analysis in the U.S. Department of Agriculture

Howard W. Hjort

We in the Department of Agriculture (USDA) are proud to co-sponsor this conference with the Farm Foundation, the American Agricultural Economics Association and the Food System Research Group (NC-117).

I understand that the proceedings of this workshop will be presented as a special issue of the *American Journal of Agricultural Economics*. This is as it should be. The topic for discussion at this session is important. Given the policy setting, it is essential that we talk about the need for objective assessments of regulatory actions.

Your conference program reflects a broadened view of the regulatory process. It evidences a recognition of the legal and political aspects of policy decision making. It establishes a challenging research agenda—one that, as accomplished, will help to shape the regulatory process.

There was a time when food system research economists interested in regulation thought primarily of measuring the costs of rules that somehow interfered with market processes. The topics were narrowly defined. The increased costs associated with environmental protection and worker safety were routinely assessed. Less routine were studies to assess benefits. Until recently, commodity policy research was not considered as regulation research. But the policy setting today makes such a broadened view essential.

The Policy Setting

The past several years have been characterized as a time of opening of the public decision-making process. The broader involvement of interest groups in issues dealing with the environment, work conditions, health and safety and the extent of competition in industry is a reflection of this changed policy setting.

Howard W. Hjort is Director of Economics, Policy Analysis and Budget, U.S. Department of Agriculture.

For agriculture, this opening of the decision process has resulted in broadening the scope of the issues routinely considered. More and more, the focus of the policy problems we deal with is on food. The food policy we talked about developing just a few years ago is quickly evolving. The concerns of Congress are also more food oriented—and Congress increasingly relies on economic information in making decisions.

The Congressional Budget Office, the House and Senate Budget Committees, the General Accounting Office and the Congressional Research Service, to name a few, are all adding to the analytic process.

This evolution of the policy process is putting intense pressure on the traditional institutions. Regulatory agencies, once comfortable in working closely with those being regulated, are opening the process to others affected by their decisions. The system is beginning to recognize that all decisions imply gainers and losers, and that both parties need to be involved in the decision process.

The Department of Agriculture's Response

The USDA, as a cabinet-level department involved in regulatory decisions, is responding in a positive way to this changed involvement. We are shaping the day-to-day operating procedures in a way that helps us make better decisions by incorporating information from all affected parties.

Early on, we established a framework for obtaining and using input from the public. USDA's Office of Public Participation is housed in the Office of the Director of Economics, Policy Analysis and the Budget.

Public participation in government decisions serves two important purposes: (*a*) It is a source of information for decision makers on attitudes and alternative approaches to proposed programs; (*b*) It assures the public, by means of an open decision process, that government actions are properly conducted.

It is important that public participation be viewed as an integral part of the decision-making process. It is also constructive to state what public participation is not:

(*a*) It is not public relations or the publicizing or promotion of agency programs.

(*b*) It is not a one-sided process of seeking support for agency positions.

(*c*) It is not a ritual fulfilling of a requirement. Unless the public input is analyzed and used, the legal requirement is not truly met.

(*d*) It is not a poll on whether a statutory authority should be carried out. The quality, not the quantity, of the comments affects the decision to be made.

The decision calendar, which is now made public, also helps open up decision making. Those likely to be affected by our decisions are now informed as to when a decision will be rendered.

In addition, impact analysis now is required for all regulatory decisions. This analysis is reviewed and must be approved on all major regulations in the Office of the Director of Economics, Policy Analysis and Budget.

These impact statements are taken seriously—they are not simply perfunctory statements which meet some legal requirement. They are the record of how the decision was made. They show the alternatives considered and the projected impacts of the action.

Every decision by an executive agency constitutes a part of the record of the administration of the incumbent President. President Carter has extended his oversight to all government regulations, major and minor. He has established oversight mechanisms to focus on the number of regulations, their necessity, their burden, their clarity, and their impact on society and the economy (see Appendix).

The need for analysis as the documentation of the basis for decisions or programs is a more recent requirement than the established clearances for legal authority or budget authority. It has become necessary for two primary reasons: (*a*) because the volume of administrative rule making has become so large that restraints on arbitrariness are absolutely essential, and (*b*) because secondary impacts of federal actions can be as far-reaching as the primary benefits and both must be understood.

An adequate impact analysis forms the decision record. It provides the preamble for public notice, it responds to public comment, it documents environmental impact assessment and other required analyses and incorporates by reference other studies, consultant reports, transcripts or memo records of meetings.

Finally, in the Working Group on Food and Agricultural Policy, representatives from across the government are involved in discussions where options are considered. This way we are able to ensure that the broader national and international issues are considered before a decision is made.

Role of Economic Research

As should be obvious, such a process puts increased pressure on the product of our economists. They too are challenged to broaden their perspective—to consider the public good.

In a process such as I have described, the advocacy groups cannot be relied on for objective analyses—such analysis is often not in their best interest. Even if the research they do is objective, it is likely that those with opposing views will be successful in reducing its credibility.

Such a setting then gives rise to the need for more involvement from public sector analysts. Such analysts are in a unique position to improve the decision process.

Issues can be identified, and potential adjustment costs made explicit and public prior to the debate.

It is not our place to dictate social or political objectives—that is a task for the political system. However, once the goals and objectives have been voiced through that system, economists can identify and evaluate the economic consequences implied by the options for achieving those objectives.

We have a responsibility to influence the policy agenda by conducting good research and communicating the results in a way which brings significant economic issues to the public's attention. Innovation and creativity are vital in policy analysis.

ESCS Expands Research

To that end, we have redirected some of the resources in ESCS to research on topics dealing with contemporary regulatory issues. At the present time, we are involved in cooperative efforts with the Food Safety and Quality

Service (FSQS), the Food and Nutrition Service (FNS), and the Extension Service, to mention a few.

In each case, the research is designed to improve the public's understanding of USDA's regulatory actions and to help make the trade-offs clearer.

Presently, for example, we are:

(*a*) establishing a monitoring program to help the Secretary of Agriculture determine whether cooperatives are unduly enhancing prices;

(*b*) conducting the Department's study of the net weight labeling proposal;

(*c*) involved with FSQS in a task force effort to assess meat and poultry inspection issues;

(*d*) participating with the Land Grant Universities in the Food System Research Group (NC-117) effort; and

(*e*) evaluating the meat pricing system.

In addition, there is an increase in resources for food safety and quality research in the President's fiscal 1980 budget.

Studying the Cumulative Impact is Important

An important but often neglected aspect of regulatory research involves the identification of cumulative impacts from the entire set of policy actions.

The Carter Administration is now involved in a major effort to slow the rate of inflation in the general economy. Since regulatory actions are often designed to internalize costs, thus resulting in increasing the accounted-for costs of producing a unit of output, their effect is often to put upward pressure on prices.

It is essential therefore that the extent of the cost-increasing pressure for each issue be known prior to making the decision.

Perhaps more important, but often overlooked, is the cumulative impact of all such decisions. Given that we have an issue-specific political advocacy process, such analyses take on added significance.

Perhaps a good example is the structure of the farm sector. For many years, our farm programs have been justified on the basis of a policy desire to "save the family farm."

There is little disagreement with a national objective of encouraging a family farm system. But the cumulative effect of our farm programs may well have been to hasten the concentration of the farm sector: (*a*) Federal tax policies provide incentives to purchase land and hold it as a hedge against inflation. (*b*) Commodity programs, too, primarily because the benefits are based on the volume of production, may have provided relatively more support to the larger farms. (*c*) Even the benefits of our Land Grant University and Extension Service programs may have gone disproportionately to those we least intended to help.

The Secretary of Agriculture has identified the farm structure issue as one of the highest priority. Recently, he called for a "full scale national dialogue" on the issue.

The structure issue is a regulatory issue. I hope you will give it consideration as a high priority research problem.

Concluding Comments

About a year ago we sponsored a series of food policy seminars. The focus of those sessions was on the food assistance programs.

This conference addresses another of the important food policy issues. In most cases, regulation research is simply policy analysis. Many of you have been involved in policy work for years. You have the tools and the experience. We look forward to working with you.

Appendix

Evaluation Criteria for Executive Order 12044: Improving Government Regulations
Office of Management and Budget (OMB)
April 10, 1979

The President has directed OMB to report semiannually on the effectiveness of Executive Order 12044, "Improving Government Regulations," and agency compliance with its provisions. The evaluation plan outlined here will focus on the five essential goals of the Order:

I. Effective senior-level policy oversight
II. Increased public participation
III. Better and more useful analysis
IV. Periodic review of existing regulations
V. Increased simplicity and clarity of regulations (plain English)

The evaluation plans outlined here give agencies an opportunity to review and critically assess their own performance in these five areas and to provide OMB with documentation of their accomplishments and shortcomings.

In addition, OMB will conduct case studies, from time to time, of individual regulations to determine whether they were developed according to the letter and spirit of the Executive Order.

We will also seek comments from the public on specific agency practices and the effectiveness of the Order in general.

I. Effective Policy Oversight

The Order requires heads of agencies and policy officials to exercise effective oversight of the development and implementation of agency regulations. This requirement is intended to raise the level of regulatory decision making within agencies so that policy officials with broader perspectives and responsibilities can balance the other more parochial interests of technical staff. We believe that more effective policy oversight is the key to the implementation of many of the other provisions of the Executive Order, such as regulatory analysis, public involvement, and clarity. Without it, realization of the other objectives may be impossible.

There are three stages at which the Executive Order requires policy-level oversight for significant and existing regulations:

1. Approval of the semi-annual agenda of regulatory actions;
2. Review, before development begins, of the issues, the alternatives to be explored, plans for obtaining public comment, and target dates for completion of each step in the development process; and
3. Approval before final publication.

The most useful appraisal of agency compliance with this provision should come from case studies of selected regulations, from frank appraisals by the agency staff, and from information supplied by members of the public. Agencies are required to describe in detail several examples of how they carried out this provision of the Executive Order for their significant regulations. Agencies should also tell us, using examples, the effects of this provision of the Order: What major recommendations were disapproved at the policy level? What improvements, if any, were made as a result of better policy oversight? If delay was a problem, agencies should describe those cases in detail, including the reasons for delay and whether or not the quality of the regulation was affected.

OMB will conduct case studies of the development of selected new regulations and the review of existing ones as a supplement to these agency reports. These case studies will enable us to make objective, informed judgments on the effect of the Order and Individual agency performance.

II. Public Participation

The Executive Order requires that the public be offered an early and meaningful opportunity to participate in the development of agency regulations. In the past, regulatory proposals have not always reached the public in a timely, informative manner. The requirements of the Executive Order are intended to ensure that the people who are affected by the regulation—those who pay the costs or receive the benefits—have an opportunity to alert federal regulators to the effects and potential problems of the proposed regulation.

To give the public adequate notice, the Order requires agencies to publish at least semiannually, an agenda of significant regulations under development or review. In addition, the Executive Order encourages agencies to achieve greater public participation in several ways: (1) by publishing an advance notice of proposed rulemaking; (2) by holding open conferences or public hearings; (3) by sending notices of proposed regulations to publications likely to be read by those affected; and (4) by notifying parties directly. Agencies are to give the public at least 60 days to comment on proposed significant regulations, except in certain rare instances. This requirement is intended to improve agency decisions by giving the public more time to prepare informed comments.

In their progress reports, agencies will describe, using specific examples, what methods have been used to publicize proposed agency actions and to solicit public comments. Agencies should further describe: (1) which approaches (e.g., hearings, public notices, etc.) resulted in the most useful comments, (2) which were largely unsuccessful, and (3) why.

Agencies should also describe whether expanded opportunities for public participation were given as a general rule, only occasionally, or just in certain cases, such as for proposals with major economic effects. Have efforts to increase public participation resulted in a wider variety of respondents (e.g., more individuals, businesses, state and local governments)? If public comment has increased, has this helped or hindered the agency? How? Where possible, agencies should give examples of significant actions taken in response to public comments, such as withdrawal of a proposed regulation, major changes in the number of people or businesses affected, or significant reduction in cost.

III. Regulatory Analysis

Regulatory analysis is intended to focus agency attention on the economic consequences of regulatory decisions and to ensure that intended regulatory goals are achieved effectively at the least cost. The Executive Order requires agencies to prepare a regulatory analysis for significant regulations which are expected to have major economic consequences for the general economy, individual industries, geographic regions or levels of government. These analyses are to be made available to the public.

While we will be tracking the agencies' regulatory analyses, each agency should provide its own assessment of how this provision worked. Were the analyses, as a rule, completed early in the formulation stages of a regulation? Was the least burdensome of the acceptable alternatives chosen? If not, were reasons provided to the public? Agencies should discuss and provide examples of how the

analyses did or did not contribute to the formulation and design of the regulation. For example, where in the agency were the analyses prepared, by program people or by a special analytical staff? If this varied, which approach was most useful and why? Who in the agency found the analysis to be most useful—program managers? Management analysis staffs? Policy-level decisionmakers?

IV. Existing Regulations

Agencies are required to review periodically their existing regulations to see whether each is achieving the policy goals of the Order. Those reviews are subject to the same procedural steps outlined for proposed new regulations. They are intended to help weed out unnecessary regulations and to improve essential ones. Agencies should report how effective their reviews of existing regulations were. We would like to know what difference their reviews made. For example, were unnecessary paperwork requirements eliminated? Was the meaning of the regula tion clarified? Were better, less burdensome regulator approaches discovered and implemented? Were any regu lations recommended for outright elimination?

V. Plain English

So that individuals who must comply with regulation understand them, the President has directed agencies t write regulations as clearly and simply as possible. Al though this is an extremely important requirement of th Order, plain English is difficult to define and measure Some regulations must be written in technical language but at a minimum, the preamble should be clear and un derstandable to the lay reader. We would appreciate hel from the public and the agencies in identifying especiall good and especially poor regulations. We will report to th President which agencies continue to issue confusing reg ulations as well as identify those agencies that issue ex ceptionally clear and well-written regulations.

Politics and Regulation
(Richard King, North Carolina State University, Chairperson)

The Politics of Policy Analysis

Nina Cornell

What I would like to do today is to share a little bit of my experience in trying to influence policy, and to share with you some of the things that I have learned about trying to influence policy through using analysis.

Let me start by laying out explicitly a couple of my assumptions. I am assuming that by policy analysis we really mean economic analysis directed to policy issues. And, I am going to make clear that I am confining my remarks to the regulatory context. By that I do not mean the context in which we find out what legislation ought to be passed to set the framework for regulating in any particular area. I mean the context in which an agency starts to exercise its discretion to deal with any particular fault, problem or issue for which a regulation or a set of regulations is required by law.

Politics really seems to me to mean having some influence in making changes—in other words, communicating and winning. I am going to discuss both because maybe they do not mean the same things any longer to me that they mean to people outside of government.

I think we have to realize the facts of life. First of all, policy analysis can come either before or, unfortunately, after a decision has been made. If after, no politics really are involved. In that situation, the decisions on the policy and the regulation already have been made, and policy analysis is just window dressing to try to justify the decision after the fact.

I really want to address the rest of my comments to the case where policy analysis is truly coming before the decision or, more accurately, before each stage of the decision because there usually is not just one decision point. In the case of regulation, by which I mean rule making either formal or informal, you start with a notice of proposed rule making, and hearings are held at several stages along the way before final rules are issued. During this period, everyone has the opportunity to influence the final decision.

Nina W. Cornell is Chief of the Office of Plans and Policy, Federal Communications Commission, Washington, D.C.

Communicating

When I talk about communicating and having influence, they really mean the same thing. Effective communication enables you to influence somebody. There are some essential keys to effective communication.

First, no jargon. I cannot tell you how many people walk away the first time you say marginal costs. They do not know what it means and trying to define it after you have used the word marginal is far worse than never using the word at all. Start with what you say it equals and never mind the jargon. You can bring that in later. Second, in trying, at an early stage, to get a decision maker to start looking at what ought to be done and how the problem ought to be structured, keep it as brief as you possibly can. Third, make sure that what you tell the decisionmaker at that stage is relevant to the decision. It is not the stage for a long history of the affected industry. He or she does not have time.

Knowing the Law

The next thing about politics or influencing decision making is being conversant with one particular basic law. It is important to know not only the law that sets the regulatory framework, but also the Administrative Procedures Act, because every rule and regulation has to conform with it. Most important is to understand the standards set by that Act for judicial review of an agency's action.

Informal rule making involves putting out a notice of proposed rulemaking and asking for

comment. This is called notice and comment rule making. The standard of review for this kind of rule making requires that whatever decision is made must not be arbitrary or capricious based on the record available to the decisionmaker. I stress that because it brings us to the question of what the record is, how important it is, and how valuable it can be for the policy analyst to know how to use the record. With that knowledge, the analyst can push a decision in the direction he or she thinks the decision ought to go. The record is equal to everything filed in a docket, which is the way agencies usually refer to any formal or informal rule making. The record is everything filed by outsiders in response to a proposed rule making in the *Federal Register,* plus any in-house studies performed. People will send in comments by the deadline, there will be reply comments after another deadline, and maybe another round of answering each other's comments. Everything the agency has analyzed is made available to the decision maker up to the time the rule is promulgated; anything received after that cannot be used by the agency to justify a decision. The decision must be made on the basis of the record available to the decision maker at the time he or she finally says, "This is the rule I am going to put out."

Formal rule making has a higher standard. It has to be based on the *preponderance* of evidence in the record before a decision maker can make a decision. That is why we find that formal rule makings usually involve such things as adjudications or license grantings. We see a lot of that at the Federal Communications Commission (FCC). When you cannot tell clearly which of the two candidates is most qualified to get a single license, a formal adjudication can go on for years because the preponderance of evidence on the record must support your position or else you get taken to court. And the court will say that you did it wrong; you should go back and do it again. So it goes on forever. We have license cases that go on for seven or eight years because you are trying to count how many angels dance on the head of a pin—you have to have a preponderance of the record on your side.

Informal rule making applies to most of the major regulations—the ones which have major economic impact usually involve informal, not formal rule makings. One way to characterize these cases is that the decision must fall in the realm where reasonable men can reasonably disagree. The first rule for economists in dealing with lawyers is to come to understand somehow why it is that lawyers think that the word "reasonable" is very precise. They think that when I talk in economic context I am being very imprecise, but they will hold up a reasonable standard as something very concrete and rigid.

If you understand all this, if you really can put those pieces together, you can apply this to make a difference in the decision.

I am going to pick an agricultural example, though I have very little background per se in agriculture. Take an agency facing the question of whether to ban or curb the use of nitrates and nitrites in bacon. You want to be sure that the decision is economically based. My basic definition of economics is that, in a very fundamental, not necessarily quantifiable way, economics means looking at costs and benefits. Efficiency is achieved when the benefits exceed the costs. If you have more than one choice, you pick the one that has the largest excess of benefits over costs. Again, I do not mean that in a quantifiable way. I am not here to argue about what is the proper social rate of discount or any of those other quantifying problems that arise in numerical cost/benefit analysis. A decision like the nitrite/nitrate-in-bacon decision, however, should be based on a clear understanding of the costs and benefits: what will it cost if we take them out versus what will we gain if we take them out.

Suppose you, as an analyst, are starting that one from the beginning. The first thing to do is to lay out to the decision maker a brief jargon-free memo that tells him or her what this question really involves. The question is whether or not we continue to allow nitrates and nitrites in bacon, and the decision maker has some very real choices. It may be that the choice is no additives and no bacon versus bacon and additives. Or, the choice may be no additives and very high increases in the cost of bacon versus continued additives and continued low-cost bacon. Or, it may really be no additives at the cost of a one-time change in the way bacon is processed, a short-term rise in price, but maybe no long-term real rise in real terms in the price of bacon. In other words, it may mean only a temporary disruption to the industry.

You will have to be credible as you write that memo. If you predict how the public is going to react—the extremes from Ralph

Nader and the public interest law firms on the one hand, and from the bacon industry on the other—you may display how reasonable you have been in comparison to those extremes. You will have predicted accurately what is going to be said once the proposal becomes public.

Using the Record

This kind of regulation has to be done through a notice and comment rule making. After the decision on what is to be put out for public comment has been made, it is important to be conscious of what the record means to the decision. It is now time to do a detailed analysis of the costs and benefits, particularly the future costs and the future benefits, and to make sure it gets into the record. Put it out for public comment. A lot of economists really do not want their analyses out for public comment. They are concerned that every detail in their analysis may not be correct. You can always put it out with caveats—that it is a draft, noting that all the numbers have not yet been checked and that indeed there is further work to be done.

At this point, it may not get you an "A" as a term paper, but it can have an impact. If you put it out for comment, even as a draft, and people comment on it, you then multiply the amount of the record that deals with the set of issues that you believe ought to face the decision maker. You have taken that record and made it focus on the set of issues that you, as a policy analyst, think are the important issues. As a result, the decision maker will have to focus on the issues and the kind of cost/benefit approach that you are trying to introduce in the process of doing policy analysis. You are making the record work for you.

There is another point I want to make. Speaking as the economic historian I once was, I can say very forthrightly that this still is not the time to do an accurate economic history of hog production since 1900. It will have little role in the decision process. It may be excellent economic analysis, but it is not policy analysis. That goes back to my comment about the future costs and future benefits. It may be that a policy analyst will find an accurate detailed economic history of hog production since 1900 to be very useful. It will tell the policy analyst what options are viable or not viable based on past experience. And it will also help the analyst to figure out some of the costs and benefits that he or she may not have thought about. But it is not policy analysis. It may be the raw material, but it is not policy analysis.

Burden of Proof

In addition to using the record and the Administrative Procedures Act and the standards of judicial review, you should be aware of the importance of where the burden of proof lies. The person who has to prove something is always at a disadvantage compared to the person who can sit back and wait for it to be proven. Therefore, the way the decision choices are structured, both for the decision maker and in a notice and comment period, makes a big difference to the outcome.

To go back to the blatant example of the nitrites and nitrates in bacon: if the burden of proof were on proving nitrates and nitrites safe, we would have seen bacon without nitrates and nitrites on the shelf at the first mention of possible risk. Whether that is good or bad is something I am not addressing here. The point is that it is very tough to prove safety beyond a shadow of a doubt. Even to prove something harmful beyond a shadow of a doubt is quite difficult and takes quite a long time, although it is easier. If you had to prove nitrates and nitrites safe they would be removed immediately and they probably would be out for a long period of time even if ultimately they were proven safe and let back in. Our system, however, leaves them in until proven harmful, so they have stayed in for a long time since the questions were first raised.

For a more subtle example, I will turn to the field of communications. The Federal Communications Commission has issued a Notice of Inquiry, which is something like an Advanced Notice of Proposed Rule Making in which the Commission, because of court decisions, is looking at the question of whether there should be open entry or restricted entry in the provision of simple long-distance telephone service. It is an either/or situation. You have open entry or you have restricted entry. Restricted entry is what we had until the U.S. Court of Appeals of the District of Columbia ruled that the FCC did not have the right to prevent entry unless we made a public interest finding that monopoly was in the public interest.

If the court had made the other finding, there would still be restricted entry, and it would go on for years while interested parties tried to make the case that competition was more beneficial. In the total absence of data—because the available market data is past data based upon restricted entry and upon obsolete technology—we would be trying to argue something that cannot be proven. And it would be litigated. If we tried to do it, we would get litigated and litigated, and maybe we would finally win and finally be able to open entry.

But the court reversed that by saying that the FCC had to permit open entry unless we made a finding that monopoly was in the public interest. Suddenly the burden was on the other shoulder. It was up to those who wanted restricted entry to prove that it was in the public interest and beneficial. Now they find themselves with stacks of past data based on obsolete technology. So it is not going to be very useful for them to talk about what it would be like in the future if we restricted entry and allowed only one provider of long distance telephone service.

Notice how different the outcome is now likely to be. It will still get litigated unless Congress succeeds in settling it legislatively by amending the Communications Act this year, and it may get litigated even so. In the meantime, there is going to be open entry while those who want restricted entry continue to litigate. If the burden of proof were still on those who want competition, restricted entry would stay in effect until the litigation ended. You should not underestimate the power of putting the burden of proof in one place or another. It may be one of the most important factors in determining what decisions get made.

Strangely enough, one of the most important factors in making policy analysis influence decisions has to do with bureaucratic structure—in particular, the bureaucratic relationship of the analyst to the decision maker. An economist or a policy analyst wants to have an impact on the decision. It is most important that the decision maker has a stake in the work that the analyst does. The best way for that to happen is for the analyst to work for the decision maker. Because, then, as that analysis becomes public, the decision maker, as the boss, has to stand up for the work his or her staff has done. The decision maker has a stake in it; it is important. The worst bureaucratic relationship is for the analyst and the decision maker to be co-equals reporting to separate bosses. Then the decision maker has no accountability—no stake in that analysis. Therefore, there is no real reason that he or she has to take it into account, stand up for it, defend it, answer to it. Earlier I heard a speaker talking about analysis, bureaucratic structures and so on. They are important and they do make a difference to the decisions that are made.

Winning

At this point, I would like to talk a little bit about what winning means around Washington. The first rule of Washington is that nobody gets everything they want all the time. And, in many cases, getting the decision in a regulatory context based on a full cost/benefit analysis is a massive victory. More of them are happening in Washington every day, but it still amounts to a massive victory. A full analysis means including the costs to society not just to one industry or one part of an industry. It looks into the future not just the present and the past. It looks at all the benefits to society, again not just to one small group or one small class. It has to deal with who wins and who loses all across the board.

The second thing about winning is attitude on the part of the analyst. To keep one's mental health in Washington, one has to be able to see glasses as half full rather than half empty. I hope I have outlined ways in which to make glasses slightly more than half full.

Economists, Regulation, and Public Policy

R. James Hildreth

A number of laws establish regulations that apply to the food and agricultural industry. These regulations reflect public policy regarding the physical, social, and economic environment within which the industry operates. As Jim Shaffer has stated: "Economic regulation results from the attempt of citizens to articulate preferences about the physical and social environment they share. There are many problems in the articulation of preferences by both market and political processes. Economics supposedly deals with the mechanism for expressing preferences as guides to production of goods and services . . . There are no simple solutions to the problems associated with the enactment, design, implementation and evaluation of economic regulation. But it is possible to provide understanding which can lead to improvements in the regulatory system and performance of the political economy" (p. 5).

This paper explores the role the economist should play in the process of establishing public policy that regulates the food and agricultural industry.

The Changing Regulatory Process

Until the past few years, it was fitting that many students of regulation described the political relationships between the regulated industry, the regulatory agency, and the congressional subcommittees with jurisdiction over the agency as an "iron triangle." The dominant position was held by business, but it had to operate within the discipline and constraint of the "iron triangle." It was agreed that the regulatory agencies often did not serve the public interest, but promoted special interest at the expense of the public. While businessmen would complain about regulations, they did not strongly oppose them.

While most economists agreed that the purpose of government regulation of business was to cure competitive imperfections in the marketplace, some argued that regulation was a technique firms used to escape the competitive forces of the marketplace. Most scholars recognized a comfortable and cooperative relationship between the regulator and the regulated. The congressional acts creating the regulatory agencies were general statements giving those agencies extremely broad powers, and they provided little specific policy guidance except to tell the agency to act in the public interest. Most of the agencies were organized on an industry-by-industry basis—for instance, the Interstate Commerce Commission, the Civil Aeronautics Board, and the Federal Communications Commission.

But things have changed on the regulation scene, and horror stories of regulation abound. An example was given at the 1976 Public Policy Education Conference by William Allewelt, president of a cooperative canning enterprise in California. A mold named geotrichum exists wherever summer fruits are grown, and it is impossible to avoid the mold in commercial canning operations, as well as in household kitchens. The mold is viewed as totally harmless by the industry. However, under the applicable regulations of the Food and Drug Administration (FDA), there was no tolerance for this mold. This meant that when FDA decided to be concerned about the mold, they had to enforce a zero tolerance. The cooperative was forced to move from three seven-hour shifts to two shifts working nine to ten hours each in order to allow cleaning operations to reduce the level of the mold. The estimated loss was 1,800 seasonal jobs in the communities where the fruit canning plants were located. Allewelt estimated the total cost to the cooperative for the entire incident was at least $2,000,000, eventually resulting in a loss of $500,000 for the fiscal year.

The conventional wisdom about regulation a few years ago would not have allowed for the cry of anguish contained in Allewelt's story. Weaver argues that the reason for anguish is that there is a "new regulation" which is quite different from the "old regulation."

The "new regulation" agencies were estab-

R. James Hildreth is managing director, Farm Foundation, Oak Brook, Illinois.

Many of the ideas in this paper were contained in the author's paper, "Public Policy and Regulation," presented at the Northeast Agricultural Economics Council Annual Meeting, June 1978.

lished to operate as adversaries of the interests they regulate, according to Weaver, rather than in the comfortable, cooperative relationship between past regulatory agencies and the regulated. The laws under the "old regulation" establishing the agencies were short and provided little specific policy guidance. The "new regulation" legislation is very lengthy and very specific. The possibility of capture by the regulated is minimized, since the "new regulation" agencies are organized along functional lines with their jurisdictions cutting across industry boundaries. The "new regulation" laws often give nearly any interested person a standing to sue the agency for failure to do precisely what the law tells it to do. Weaver reports that the new agencies lose most of the court cases. Further, Weaver holds that the "new regulation" agencies operate with little or no concern for the cost or consequences of their pursuit. "The EPA [Environmental Protection Agency] for instance, is explicitly forbidden by law to pay attention to the cost in setting and enforcing the nation's primary ambient air quality standards" (p. 52).

The traditional "iron triangle" is no longer at work. Many of the advocates of the "new regulation" are strong in their opposition to the "iron triangle" of the "old regulation." Should an agency appear to be operating in the mode of the traditional "iron triangle," the public interest groups will bring court suit to put the agencies back on the straight and narrow. Supporters of the "new regulation" often argue for deregulation of the airline industry, as well as of the trucking and communications industries.

The opponents of change have even learned to use the courts and the "new regulation" to achieve their ends—witness the opponents to enforcement of the 160 acre limitation on irrigated land successfully bringing suit to require an environmental impact statement on the effect of enforcing the 160 acre limitation.

The Economist's Role

Under the "new regulation," open conflict exists. The established business interest groups are screaming at the public interest groups, and the public interest groups scream back. Suits are brought in court. Charges and counter-charges between the agencies and firms are put forward.

Weaver points out that, from the point of view of political scientists and journalists, regulation is a part of the battleground for the ongoing conflict between private interest groups and the public interest. He suggests the "new regulation" may be more a social policy than an economic policy.

Under the neat economic arguments of the "old regulation," one could use data and logic to determine if the competitive market structure was flawed and then initiate regulation to modify performance. But under the "new regulation," the arguments are much less straightforward. And very little useful information goes to Congress, which could trigger changes in the laws that started the entire process.

The optimum amount of regulation is difficult to define. An attempt to internalize the external costs placed on society by the actors in the marketplace is the rationale for much of the "new regulation." Determining the optimum amount of internalization and accompanying regulation is most difficult. Internalization usually involves major changes in the property rights of individuals, as well as placing value on items that are not exchanged in the marketplace.

Is there a role for the economist in such a regulatory setting? I think there is an important role, and I will give you my views on what that role is and how it might best be performed.

The traditional public policy research and education mode provides economists with a useful approach to regulation. This mode involves defining the policy issues, developing alternatives to deal with the issues, and then predicting the consequences of the various alternatives. Economists have made major contributions to public policy developments within this framework for years. Regulation policy research under this framework can make significant contributions to the debate and dialogue. Economists can play an important role in helping to identify the critical issues, prescribing alternative approaches for handling the issues, predicting the impacts of the approaches, and assessing the degree to which regulations achieve their original objectives.

Policy research and education is often viewed as problem solving by the social science community. Much of the frustration of both social scientists and politicians is explained by this view. The question of how policy research can help policy formulation

has been examined by Rein and White. They state: "The long-standing problem-solving model is in large part a myth. Research may solve problems, but it also has three other important functions: 1) identifying problems as a step toward putting issues on the agenda, 2) mobilizing government action, and 3) confronting and settling dilemmas and trade-offs" (p. 130). They also hold that the search for an issue is the lifeblood of politics; that policy dilemmas involve a conflict of values; and that politics is quite different from science. Their ideas are cited to illustrate the validity of the agricultural policy research and education mode, which has been used effectively for decades.

Four kinds of research studies were suggested by Dale Dahl, University of Minnesota, at this conference: (*a*) Pre-legislation research—the study of the predicted consequences of alternative "rules" or methods to achieve policy goals; (*b*) Post-legislation research—the study of effects of the regulations implemented in terms of meeting the policy goals; (*c*) Administrative agency research—the study of the ability of an agency to administer "properly" a set of regulations to achieve their charge, in other words, the economics of bureaucracy; and (*d*) Cumulative effect research—the study of the cumulative effect of a mix of regulations on a sector or sub-sector of the economy. The issues, alternatives, and consequences mode is useful for each kind of research study suggested by Dahl. However, the issues are different for each kind of research—the issues for pre-legislation research are not the same as administrative agency research.

Identifying Issues

The "old regulation" issues seemed much simpler, since they focused primarily on obtaining sufficient competition. Much of the "new regulation" legislation passed in the late 1960s and early 1970s focuses on concerns for the environment, health, and safety. The rise of the consumer movement and the reduction in legitimacy of science and the political process played a role in obtaining that legislation. The current concern about inflation has raised issues of price effects, costs, and effectiveness of regulation, as well as the impact on capital investment and jobs. But the identification of significant and fundamental issues in current regulation policy is difficult.

Much of the "new regulation" deals with safety: food safety, worker safety, and environmental safety. The current policy debate about risks appears unsatisfactory. In the past, the usual process to resolve risk issues was to rely on expert opinion. Today, no useful process for generating a consensus of experts accepted by citizens, scientists, and government exists.

Further, the term "safety" is often ill-defined for use in determining regulatory policy. Lowance defines a thing to be safe "if its risks are judged to be acceptable" (p. 7). Under this definition, safety is always relative and judgmental. Lowance holds that two activities are necessary to determine safety: "*measuring risk,* an objective but probabilistic pursuit; and *judging the acceptability of that risk (judging safety),* a matter of personal and social value judgement" (p. 7). It appears more useful to define safety as Lowance does than to define it as the achievement of zero risk. The policy debate would be greatly improved if citizens had some idea of the probability of a "bad" event, and a way to make social judgments about the acceptability of levels of risk.

Clear statements of specific issues will lead to useful and effective regulation policy research and education. The most difficult part of policy research and education has always been definition of issues. Understanding and insight of production and marketing processes, as well as political and governmental processes as they apply to the problem under consideration are required. Economists are surely in a position to aid in this process.

Prescribing Alternatives

Charles Schultze, in his book, *The Public Use of Private Interest,* raises two specific and separate questions: (*a*) whether government should intervene, and (*b*) how? He states: "The basic theme of this book is that there is a growing need for collective influence over individual and business behavior that was once the domain of purely private decisions. But as a society we are going about the job in a systematically bad way that will not be mended simply by electing and appointing more competent officials or doing a better analysis of public programs" (p. 5).

The alternatives for dealing with regulatory public policy issues may be grouped under the two categories given by Schultze: to intervene

or not, and how. Little attention has been given to the how. Schultze says: " . . . we usually tend to see only one way of intervening—namely, removing a set of decisions from the decentralized and incentive-oriented private market and transferring them to the command-and-control techniques of government bureaucracy. With some exceptions, modifying the incentives of the private market is not considered a relevant alternative . . . Instead of creating incentives so that public goals become private interests, private interests are left unchanged and obedience to the public goals is commanded" (p. 6).

The contrast between the method dictated by the basic legislation of the Environmental Protection Agency and the legislation dealing with conservation of agricultural land in the 1930s is interesting and instructive. For EPA, reduction of erosion is a means of obtaining clean water; for the legislators of the 1930s, reduction of erosion was a means for assuring the long-term productivity of land. Both programs have the reduction of erosion as a significant objective. EPA was guided toward heavy use of the setting of standards and issuance of regulations, that is, "command-and-control." The 1930s legislation guided the USDA toward the use of technical information and education, as well as provision for cost-sharing of conservation practices.

The methods for obtaining performance are alternatives in the issues, alternatives, consequences framework. Seldom does the political debate include the implementation methods. Consideration of alternative implementation methods and the consequences of alternative methods would greatly improve the quality of the debate. The usual policy alternatives of whether or not to intervene are not sufficient.

A paper by Seitz and Spitze which analyzes alternative policies to achieve control of nonpoint sources of water pollution is one example of the economist's contribution to improving the policy debate. They proposed a system for policy development of state plans including component steps and ways to achieve each step. The alternatives presented are persuasion (education), state investment, economic incentives for the farmers and mandated performances. This kind of thought and analysis should lead to more efficient and effective determination of society's preferences.

Alternatives to standards and inspections to improve occupational safety and health are presented by Nichols and Zeckhauser. The first alternative is provision of information. Current government efforts do include provision of information, but the resources devoted to information are tiny relative to those used in setting standards and enforcement. The authors state: "Better information should increase the efficiency of private markets, and will increase equity to the extent that it increases the workers' awareness of the risks they face and enables them to demand compensation or protection" (p. 63).

Incentive mechanisms—for example, the levying of taxes for injuries—is the second alternative identified by Nichols and Zeckhauser. An injury tax would create incentives for the employer to improve safety programs and control a whole range of factors which contribute to accidents, including safety training, rather than just correcting the limited number of physical conditions directly regulated. Safety could be made to pay for the employer and the employee by modification of workmen's compensation. While incentive mechanisms are less promising for occupational health, ways can be found to tax the employer for providing the kind of poor environment which leads to poor health in the workers.

As every policy worker knows, there is always the alternative of a combination of other alternatives. A combination of information, incentive mechanisms, and standards may be a much more attractive alternative than the use of only one method in achieving the goals of the Occupational Safety and Health Act (OSHA).

Predicting Impacts and Evaluating Effectiveness

The economist can play a very important role in predicting the impacts or consequences of implementing the alternatives. And, after the regulations have operated for a time, the economist can evaluate their effectiveness in achieving the original objectives. This evaluation could lead to recommendations for scrapping the regulations, changing them, or adopting alternative approaches. Such information could improve the regulation policy process significantly.

Little information on consequences has been included in the political debate during the passage of recent regulation legislation. The

consequences of not reducing pollution, increasing worker safety, and limiting or eliminating certain substances in food were discussed, but not the consequences for productivity or effectiveness of the regulation. Horror stories unfold relating to consequences of implementing approaches which were not analyzed thoroughly enough before legislation was passed and regulations established.

The consequences of government costs can be measured. The *Wall Street Journal* for March 14, 1978 reported an interview with Murray Weidenbaum of Washington University on the cost of regulation. He stated that the forty-one regulatory agencies in the federal government had a combined budget of $4.82 billion for fiscal 1978; consumer health and safety regulatory agencies had a budget of $2.67 billion; environment and energy agencies had $1.12 billion, and regulatory agencies in the USDA had a budget of $830 million.

Wildausky argues that the collectivization of risk leads to "market socialism," that is, all costs of risk reduction do not appear in government budgets, but they are passed on to society by higher prices and reduced investment to create future jobs. He also suggests that the burdens of regulation to achieve risk reduction are distributed uniformly throughout society and makes the statement: "The very people who are supposed to benefit from collectivization of risk will turn out to be the losers" (p. 35). The measurement of all the costs and benefits of a policy, and their distribution would be useful in regulation research, though by no means easy.

The policy debate leading to the passage of OSHA legislation did not appear to include much discussion of alternatives to standards, and it only included a small amount of discussion of the impacts of the standards and enforcement method. Nichols and Zeckhauser present some post-legislation information on consequences. "The post-OSHA injury rate data fail to reveal any clear trends or dramatic improvements" (p. 52). They also point out the costs have been high: OSHA estimates the cost of complying with the standard for coke-oven emissions is between $11,000 and $58,000 per worker for the entire United States. Even now, little information is available on the effect of economic incentives or provision of information on occupational health and safety, although the costs to producers would likely be lower than the standards and enforcement method.

Summary

In conclusion, economists should be active in developing and refining the public policy of regulation. The political debate on regulation has generally been rather incomplete. It has not been cast in the issues, alternatives, and consequences framework. Regulation policy needs careful empirical analysis of sharply defined issues, considering all feasible alternatives, and predicting impacts of the alternative approaches to obtaining desired behavior and action. Finally, the effectiveness with which regulations achieve their objectives must be evaluated.

Agricultural economists, with their long, rich, and useful experience in agricultural policy, can make a significant contribution to improving the quality of the political debate on regulation.

References

Allewelt, William F., Jr. "Zero Tolerance with Changing Technology in the Canning Industry." *Increasing Understanding of Public Problems and Policies—1976*, pp. 68–75. Oak Brook, Illinois: Farm Foundation, 1976.

"Federal Regulation of Business on Rise, Budget Study Shows." *Wall Street Journal*, March 14, 1978, p. 21.

Hildreth, R. J. "Public Policy and Regulation." *J. N. E. Agr. Econ. Coun.*, No. 2 (1978), pp. 1–3.

Lowance, William W. *Of Acceptable Risk: Science and the Determination of Safety*. Los Altos, Calif.: William Kaufmann, 1976.

Nichols, Albert L., and Richard Zeckhauser. "Government Comes to the Workplace: An Assessment of OSHA." *The Public Interest*, Fall (1977), pp. 39–69.

Rein, Martin, and Sheldon H. White. "Can Policy Research Help Policy?" *The Public Interest*, Fall (1977), pp. 119–136.

Schultze, Charles L. *The Public Use of Private Interest*. Washington, D.C.: Brookings Institution, 1977.

Seitz, W. D., and R. G. F. Spitze. "Soil Erosion Control Policies Institutional Objectives." *J. Soil and Water Conserv.* 33 (1978): pp. 118–125.

Shaffer, J. "Comments on the Political Economics of Instituting Federal Regulation of Economic Activity." Paper presented at 1977 American Agricultural Economics Association meeting. Mimeographed. E. Lansing, Mich.: Dep. Agr. Econ., Michigan State University, August 1978.

Weaver, Paul H. "Regulation, Social Policy, and Class Conflict." *The Public Interest*, Winter (1978), pp. 45–63.

Wildausky, Aaron. "No Risk is the Highest Risk of All." *American Scientist*, 67 (1979): pp. 32–37.

Research Needs of the Regulated

Timothy M. Hammonds and Doyle A. Eiler

As analysts peering back from the receiving end of the regulatory funnel, we are struck by the number of factors of major importance which typically are omitted or treated only superficially in contemporary regulatory analysis. The companion feature, equally striking in light of these omissions, is the degree of certainty with which many members of our own profession present their policy recommendations.

To be sure, a balance has to be struck between complexity and capacity in any analytic model. Our point is that important considerations are being neglected for reasons completely unrelated to capacity considerations.

We will focus our attention on three specific areas which are sorely in need of greater research attention. They are: consumer input in the regulatory process, jurisdictional overlap of regulatory agencies, and the current use of industrial organizational analysis as a source of normative regulatory policy recommendations.

Consumer Input in the Regulatory Process

Most analysts accept the premise that government regulations introduce inefficiencies and distortions into the marketplace, either intentionally or as a consequence of substituting social for economic processes (for example, Samuels, p. 100). Indeed the very purpose of regulation is to alter the performance of the economic system for the benefit of an identifiable or imagined constituency. Thus, the regulatory debate is inherently political.

The primary purpose of this political process is the reconciliation of the interests of the beneficiary constituency with the interests of those who must bear the cost. For food industry regulations, the general consuming public is typically identified as the beneficiary constituency. But, how do regulatory agencies discern the interest of the general consuming public they are trying to satisfy?

The two sources most frequently used are input from professional consumer groups and the public hearing process. Although one must not a priori reject the notion that professional consumer groups reflect general consumer attitudes, the compatibility of their views with those of the public at large deserves verification. While regulatory and legislative bodies provide opportunity for public comment through the hearing process, it is disturbing to see the government proceed as if the views expressed at public hearings are representative of consumers in general with no independent verification. The group of witnesses appearing at hearings must not be thought of as representing or even approaching a random sample of the population. They provide valuable input, certainly, but this input is not by itself sufficient.

The limitations implicit in the reliance on professional advocates and the hearing process can be overcome through the use of well-designed consumer research. Consumer research can provide the broad scale representative expression of consumer attitudes needed by regulators. Unfortunately, regulatory agencies have been reluctant to commission these studies. Two recent examples illustrate the productive role consumer research can play in the policy process.

The Federal Trade Commission (FTC) has expended considerable effort in order to create an elaborate inspection and enforcement program in an attempt to ensure the availability of items appearing in retailer ads. Recently the FTC, at the urging of its own staff, undertook an attitude survey to determine whether shoppers really suffered from the lack of availability of advertised items.

Although the final report has not yet been issued, the survey has found that only a minority of shoppers are concerned about lack of availability, that those customers who are most concerned are well aware which stores are unreliable and do not shop there, and that "the market is taking care of the problem" (Bureau of National Affairs, p. A7).

A great deal of agency effort and public expense could have been saved if the research

---

Timothy M. Hammonds is senior vice president and Doyle A. Eiler is director of research, Food Marketing Institute, Washington, D.C.

project had taken place before this particular regulation was put into place. It remains to be seen what impact this information actually will have, but it should play a major role in enforcement policy.

Food labeling provides another example of the role consumer research might play. The Food and Drug Administration (FDA), the Department of Agriculture (USDA), and the Federal Trade Commission (FTC) now are considering jointly a revision of food labeling regulations touching specifically on ingredient labeling, nutrition labeling, open date labeling, "imitation foods" designations, food fortification, and information presentation formats. As part of this reassessment process, five cooperatively sponsored regional hearings were held to solicit public opinion and reaction. The agencies were trying to solicit input from groups not normally heard. This was a worthy effort which served their purpose. However, it did not supply a random or even stratified random sample of public opinion.

Although label revision is designed almost exclusively to have impact on the purchase decision, these three agencies undertook no research to explore consumer use of alternative information presentations prior to the hearing process. In fact, there was a great deal of discussion on the desirability of graphic labeling and the need for some system of nutrition scoring without direct testing of these concepts.

To our knowledge, the only currently available consumer research bearing directly on these issues was conducted by Food Marketing Institute. A representative sample of the shopping public was polled with a standardized questionnaire supplemented with a series of focus groups to explore attitudes in depth. The research findings indicate that the list of ingredients is much more important than nutrition labeling, that a more organized form of the current label would be more effective than a totally new graphic format, and that the public has a major concern about regulatory agencies which "editorialize" rather than inform (Hammonds).

It is now time to look again at what constituency groups we really serve with each of our regulations. If it is truly the general public, consumer research must play a larger role in the decision-making process. This is not to say that the public should be polled with specific alternatives of regulatory language. But, basic attitudes, needs, and priorities must be explored. Regulatory researchers have much to learn from their colleagues in consumer market research.

This is not a call for judging the desirability of specific regulations solely on the grounds of public opinion. Neither is it a denial of the existence of non-use benefits which flow from some regulations. It is merely to say that consumer research is an extremely valuable input to the decision-making process which is almost totally neglected at present.

Jurisdictional Overlap

Along with regulatory legitimacy, we must address consistency of application. The single ingredient most certain to render any regulation unworkable is inconsistency of application. The single most effective way to guarantee inconsistency of application is to allow jurisdictional overlap among separate agencies. The food industry faces this problem regularly.

Consider, for example, jurisdiction over food labeling and advertising, which is shared by the USDA, the FDA, and the FTC. Responsibility for assuring the accuracy of statements appearing on food labels and in advertisements for food products resides primarily in these three agencies. From time to time, additional inroads may be made by the Environmental Protection Agency (for pesticide residue), the Consumer Product Safety Commission (for packaging hazards), the National Oceanic and Atmospheric Administration (covering fish products), and the U.S. Postal Service (covering mail order sales). There is currently no systematic, clearly defined mechanism for resolving the regulatory duplication and inconsistencies which are caused by these overlapping jurisdictions.

Conflict between these agencies is furthered by court interpretations of what comprises a food label. In layman's language, FDA authority extends to labeling while FTC authority covers advertising. However, several court cases suggest the FDA jurisdiction in food extends to many materials commonly thought to be advertisements. In reality, many forms of advertising fall under the purview of both agencies. This often exposes a company to conflicting standards and procedures.

Many in this audience will play a role in the President's regulatory reform program—if not this President's program, then some other

President's program. The discussion of this issue need not be prolonged because a comprehensive treatment is available elsewhere (Rill and Frank) and because the point to be made is simple. Jurisdictional overlap must be eliminated. At the very least, a formal mechanism for timely resolution of interagency conflict should be established. Businessmen have a right to know exactly whom they must satisfy. Less invites chaos. In the name of regulatory reform, let us lay this issue to rest. This is a topic which should not be left as an afterthought for agency clerks to resolve. It deserves professional attention.

Industrial Organization Analysis

Finally we come to an area of inquiry which cycles into public fashion whenever inflation intensifies. Since the Food System Research Group (NC-117) is a cosponsor of this conference, industrial organization analysis needs to be addressed. We will look at economic analysis as interpreted by laymen, the dynamic nature of competition, the need for validation of new techniques, group interaction in the marketplace, capital market imperfections, and the public policy response to "excess" power.

Analysis and the Layman

Industrial organization analysis and its policy implications are emotional public issues. Therefore, the danger of oversimplification is great. This is one topic in our profession which frequently finds its way into newspaper editorials, popularized talk shows, and platform speeches. We need to be conscious of the fact that in many cases our writing will be read not by other economists, but by laymen.

Marion and Sporleder have an important observation on this topic in an early draft of a paper they prepared for the 1976 American Agricultural Economics Association annual meeting. That is, that in the hands of noneconomists, the tools of analysis become "unbending standards of evaluation."

As an illustration, consider the Neal Report prepared by the White House Task Force on Antitrust Policy, 1968: "The term 'oligopoly industry' shall mean a market in which (1) any four or fewer firms had an aggregate market share of 70% or more during the last seven of the ten and four of the most recent five base years. . . ." (*Congressional Record* 1969, p. S5645). The Hart bill followed in 1973: ". . . monopoly power is possessed by any corporation if the average rate of return on net worth after taxes is in excess of 15 percentum over the period of five consecutive years . . . or . . . if any four or fewer corporations account for 50 percentum or more sales . . . in any year out of the most recent three years preceding in filing of the complaint" (*Congressional Record* 1973, p. S4362). Oligopoly becomes monopoly, 70% becomes 50%, and the time period for analysis shortens. Many noneconomists have picked up this theme with four-firm concentration ratios the sole criterion for judgment and 50% the sole cutoff point for monopoly power.

Carl Kaysen wrote in 1955: "It seems vain . . . to hope for more from concentration measures than that they should provide a preliminary basis on which resources for further study should be allocated" (p. 118). It is time for us to include similar cautions in our own public pronouncements. The difference between analytic techniques and policy standards deserves clarification.

The Dynamic Nature of Competition

The second and related major industrial organization topic is the persistence of market power over time. Contemporary industrial organization analysis has tended to abstract from a modeling of the dynamic competitive process to a reliance purely on structural indicators. This is a serious error.

Recent models used in Congressional testimony have been constructed to identify markets as "noncompetitive" once the sales of the largest four firms reach a norm variously identified at 70, 60, 50 or even 40% of the relevant total market. This fuels the notion just discussed that the complexity of competitive behavior may be reduced to a simple formula utilizing a single standard. It also implicitly conveys the impression that once obtained, market power persists.

There is substantial evidence that this is not the case, at least in food distribution. Folsom points out in a recent *American Journal of Agricultural Economics* (AJAE) article: "If for example, one examines the ten largest food retailing firms of 1962, he will find that three of them are not among the ten largest of 1976. Additionally the largest firm of 1962 experienced a real sales decline after adjustment for

inflation. Four of the ten largest firms in 1962 made less than 3% return on stockholders equity in 1976, with two of them actually losing money'' (p. 186–7).

Joan Robinson observes the need for considering the dynamics of the competitive process in a recent paper: '' . . . it seems to me that the research for a single generalization is a hangover from the equilibrium model. There is no simple theory to cover the multifarious evolution of a private enterprise economy . . . this knowledge cannot be well organized if it is squeezed into formulae that smooth over distinction between the future and the past'' (p. 1326).

Our primary focus should be on the dynamics of market power. Simple cross-section analysis is relatively inexpensive and readily lends itself to ad hoc policy analysis. But it is not relevant to the real competitive process. It is no more than a starting point. We must model competition as a dynamic process looking beyond simple numbers to the behavioral dimensions.

Validation of New Techniques

The introduction of a time dimension brings us to the third major issue, the validation of new techniques. An active core among our profession is developing new industrial organization theoretical constructs and measurement techniques. Since the intent is to address regulatory action and structural remedy with significant private and social cost, the need for careful validation is compelling.

In the development of any new analytical technique, there is a critical need for independent data sets for model development and for validation. The literature of econometrics addresses the severe consequences which flow from the failure to address this issue. That literature should be reviewed in an industrial organization theoretic context.

By the nature of our marketplace, the number of independent data sets is severely limited. Even portions of the early writings of Bain have been questioned by authors applying his models to the same industries with data drawn from subsequent time periods. More recent examples of the neglect of independent validation are available. There is a tendency in industrial organization analysis to use a data set to identify a competitive market norm, then to apply that norm back to the same data set to estimate market ''overcharges.'' The establishment of any market norm should be subject to independent validation.

One solution is to allow a validation period which provides additional, if not totally independent, data sets through the passage of time. There are, no doubt, other techniques which would be even more effective. Given the public policy issues at stake, careful validation of any new analytic techniques is essential.

Group Interaction

Our fourth major issue is group interaction within the marketplace. The time has long since passed when we can treat managerial discretion as if it operated in a vacuum. The popular assumption is that management behavior need be the only focus of analysis. If operating costs are high the assumption is that management has grown lax as size has increased.

We must abandon this fiction. There are many critical relationships within any major marketplace, but the most critical is that between management and organized labor. In our reassessment of industrial organization theory we must face the most glaring omission from models in current fashion: the role of organized labor.

Our profession has never adequately addressed the role of organized labor and its impact on market structure. The common models assume labor to be an operating cost, therefore, under management control, and thus, in no need of inclusion as a separate variable.

The truth is that it has been politically unpopular and occasionally personally uncomfortable to throw a realistic light on the role of organized labor. Until we have the theoretic framework and analytic tools to address this facet of our marketplace, our models cannot lead to meaningful public policy conclusions. This is the single topic which is most in need of attention in industrial organization analysis.

To be sure, the topic is complex. John Hicks points out: ''It is quite wrong to think of the labor market as being similar to the primary product market, in which price is set by demand and supply. The pursuit of fairness in labor relations has many difficult aspects; but one of the clearest and least controversial of the demands which it makes is continuity in standard of living'' (p. 102).

It would appear that our analytic heritage in the primary commodity markets is an incomplete guide. But this issue must be addressed if our analyses are to build credibility. Management is certainly not the helpless pawn of organized labor. However, the reality of the interaction should not be denied. This issue must not be sidestepped, and it must not be oversimplified. It is here that the tools of industrial organization analysis will ultimately prove their worth or their irrelevance.

Capital Market Imperfections

Our fifth topic is the presumption that advantages to size lie primarily or exclusively in the product market. As a consequence of this implicit assumption, price levels have been the focus of most models applied to the food distribution sector. In fact, there is substantial evidence, in other industrial sectors at least, that advantages to size may well lie in the input factor markets.

This concept deserves careful examination by agricultural economists. There has been work in this area, but none to our knowledge includes food production or distribution in the analytic set.

In particular, one important recent work examining the industrial sector has never received adequate discussion in our literature. In 1975, Dr. Daryl Winn published a study from the Graduate School of Business Administration at the University of Michigan. He examined 736 firms in 70 industries adjusting for risk, depreciation, and current versus historical cost reporting. He states: "Weighing the accumulated evidence from the many tests of the several hypotheses in this study, I must conclude that there is considerable doubt as to the validity of the fundamental hypothesis . . . that after the independent influences of size, capital intensity, growth, risk, and the distortions arising from historical cost accounting are accounted for, firms in concentrated industries are found to earn above-average rates of return." He goes on to say: "Clearly, if our concern is with 'excess' returns, then the cause of that concern appears to rest largely with imperfect capital markets and not imperfect production-selling markets. . . . Though monopoly power may lead to restricted output and artificially high prices, as indicated by above-average rate-of-return measures, the misallocative effects are probably not nearly so critical as those which result from imperfect competition in the money capital markets" (pp. 137–138).

This is not the last word on the subject by any means. It does suggest, however, a major policy departure from recent suggestions as to structural remedies.

The Public Policy Response

Finally, we come to the sixth major issue, the nature of public policy response. Suppose that "excess" market power is eventually identified, if not in food distribution then in some other sector. Then we face the question of what remedy or remedies should be employed.

Few would deny the terrible problems created by direct government intervention in the marketplace, even when the primary goal is widely accepted. Typically, we have thought in terms of new business regulations, structural alterations, or in the ultimate, deconcentration. Now that we have a new consumer consciousness in this country, it is time to rethink how we might use this force to impact the marketplace where previously we have looked only to direct intervention.

Our consumer research at Food Marketing Institute shows a remarkable confidence on the part of the public in their ability to make intelligent decisions given the proper information. Might it not be that improving consumer information flows in key decision-making input variables would lead to corrective behavior which would erode any "excess" market power? What better way to improve consumer welfare than to impact consumer behavior directly? We started this paper with a call to explore consumer attitudes, needs, and priorities. It is fitting that we now come full circle ending with an exploration of the consumer's contribution to corrective action.

Conclusion

We have talked about the need for consumer input into the regulatory process through well-designed consumer research, the need to address jurisdictional overlap in the name of regulatory reform, and the need to rethink the directions of industrial organization analysis.

Regulatory reform and the trend toward cost-effectiveness analysis on the heels of our tax revolt have produced the rare confluence of good politics and good economics. The profession of agricultural economics is in perhaps

the best position of any discipline to shape the direction of hard economic analysis as part of policy assessment.

Food is at the forefront of our inflation news, and, as a result, it is an unavoidable candidate for regulatory and legislative reassessment. It is equally obvious that agricultural economists are well grounded in this sector of our economy. The analytic foundation we lay must be realistic, comprehensive, and carefully communicated, for the precedents set here will have a major impact on other sectors of the economy soon to go through a similar reassessment.

Public policy is, of necessity, a process of debate, of balancing efficiency with social issues. But, if public decision making is to be effective, it should be grounded on a solid foundation of research. We now have an opportunity to bring this goal closer to reality. If we seize the opportunity without overreaching our capabilities to deliver, without substituting judgment for analysis, without ignoring the realities and complexities of the marketplace, we can make a major contribution to the public debate.

References

Bureau of National Affairs. *Regulatory and Legal Developments.* Washington, D.C. 57(1979).

Congressional Record. 91st Congress, 1st session, 27 May 1969, S5642–5659.

Congressional Record. 93rd Congress, 1st session, 12 March 1973, S4362.

Folsom, J. M. "Discussion: Competition and Regulation in the Food Industry." *Amer. J. Agr. Econ.* 61(1979):186–7.

Hammonds, T. M. Statement before the Nutrition Subcommittee of the Senate Agriculture, Nutrition, and Forestry Committee. Mimeographed. Washington, D.C.: Food Marketing Institute, 9 Aug. 1978.

Hicks, J. R. *Economic Perspectives.* Oxford: Clarendon Press, 1977.

Kaysen, C. "Comment," *Business Concentration and Price Policy.* Princeton, N.J.: National Bureau of Economic Research, Princeton University Press, 1977.

Marion, B. W., and T. L. Sporleder. "Evaluation of the Economic Basis for Antitrust Policy in the Food Industry." Paper presented at American Agricultural Economics Association annual meeting, State College, Pennsylvania, 16 Aug. 1976.

Rill, J. R., and R. Frank. "Overlapping Jurisdiction over Food Labeling and Advertising—USDA, FDA, and FTC." Legal Memorandum to Food Marketing Institute, Washington, D.C., 2 March 1979.

Robinson, J. "What Are the Questions." *J. Econ. Lit.* 15(1977):1318–39.

Samuels, Warren J. "Normative Premises in Regulatory Theory," *J. Post-Keynesian Econ.*, no. 1(1978), pp. 100–114.

Winn, D. N. *Industrial Market Structure and Performance.* Ann Arbor, Mich.: University of Michigan Press, 1975.

Regulation Analysis as a Research Focus in Agricultural Economics

Dale C. Dahl

Economics is the study of the behavior of man and his institutions as they engage in the allocation of scarce resources. Its intellectual objective is to understand the nature of this conduct and its underlying rationale. But the pragmatic reasons why economists undertake their investigations are two: (*a*) to predict future behavior and its social consequences, and (*b*) to alter (or regulate) that conduct or its effects in accord with given or perceived performance standards.

These reasons are also central to the distinction between positive and normative economic analysis (Buse, pp. 23–24); the "positivist" perceiving his role as describing, rationalizing and predicting within a given institutional framework, the "normativist" extending his study to consideration of alternative institutional mechanisms used to achieve stated public or private goals.

Economists have a long history of debating which analytical role is professionally appropriate (Bronfenbrenner, p. 7–8). While any serious study of the history of economic thought suggests that normative considerations have been fundamental to most new developments in economic theory and method, an early and lingering insistence by many practitioners on striving for a form of "scientific objectivity" (presumably devoid of value judgments) has tended to place economists into either positive or normative "camps."

The discipline of agricultural economics is both an outgrowth of the agricultural sciences and an extension of economic analysis to agricultural problems (Taylor). From its beginnings, and into the present day, agricultural economics has been distinguished as an "applied" discipline—one that initially addressed a range of social problems encountered as farmers, agribusinessmen, consumers and public bodies allocated their scarce resources to achieve various levels of food and fiber production, distribution and consumption. Now it has been broadened to include community and regional development, public decision making, and the application of economic analysis to the study of the use of other basic resources.

As the scope of agricultural economics has expanded, it has retained a real world "problem" orientation. To the extent that the problems analyzed have a "what-ought-to-be" component, agricultural economic studies are implicitly or explicitly value-laden and take on a normative character. This conclusion (or assertion) does not simplistically suggest that all agricultural economic analysis is normative in nature, but it does emphasize that various types of normative economic analysis have been a leading hallmark of our discipline.

Principally during the past two decades, an extensive literature on the subject of the economics of regulation has come into existence (Grant, 1979). While some authors have identified the 1962 and 1971 articles by Stigler as groundbreaking (Peltzman), there appears to be a consensus that these and subsequent studies are "an attempt to join neoclassical theory with 'institutional economics,' " (Kahn p. VII) and that this type of work represents a rigorous and potentially valuable example of normative economic analysis.

The purpose of this article is to explore the potential of regulation analysis—this develop-

---

Dale C Dahl is professor of agricultural and applied economics and adjunct professor of law, University of Minnesota.

The author acknowledges useful ideas and suggestions from Winston W. Grant, Glenn L. Nelson, Willard F. Mueller, and James D. Shaffer but holds them blameless for errors found in this article.

ing subdiscipline of economics—as a research focus in agricultural economics. It will be asserted that most current-day agricultural economic analysis is normative in character; that the gap between orthodox and institutional economics is being bridged or closed; and that future research must pay increased attention to legal aspects of economic questions and the economic analysis of the law.

First, it is argued here that the U.S. food system, conceived to include business activity from the manufacture of agricultural inputs, through farming, to the assembly, storage, processing and distribution of food products, is one of the most regulated of industrial groupings. It is further argued that the mere mass of statutory, common, and administrative law relating to this sector has served to discourage academic agricultural economists from expanding their research horizons much beyond the study of traditional price and income strategies, and that an educational effort is needed.

Second, it is argued that traditional normative economic analysis is only a part of an emerging methodological paradigm that can be used to address a series of significant current research problems in the food sector. This paradigm essentially extends the structure-conduct-performance interrelationship to include the analysis of alternative policy remedies and to reorder the analytical sequencing of this and other approaches.

Third, it is argued that a demonstrated range of analytical conceptions and tools that can be employed in food regulation analysis now exist. Further, research opportunities for the study of regulatory questions may be considered in terms of before-and-after regulatory enactments, in terms of the regulatory agency, charged with administrative functions, or in terms of the cumulative impact of a group of regulations on vertically-defined industrial subsectors, horizontally-defined industries and markets, or in terms of more broadly defined macroeconomic variables.

Regulation in the Food System: An Overview

Regulation economics, though heralded as a newly-developing branch of economics, is difficult to define because of an apparent lack of agreement on what is meant by the term "regulation."[1] A review of the literature reveals a spectrum of definitions ranging from broad to narrow in conceptual scope.

At the broadest extreme, regulation refers to the "full pattern of government intervention in the market" and includes "taxes and subsidies of all sorts as well as to explicit legislative and administrative controls over rates, entry and other facets of economic activity" (Posner).[2] The narrowest definition encountered states that regulation refers to the process by which administrative rules are promulgated, applied and adjudicated in an effort to articulate and enforce legislative enactments (Russell).

The definition used in this article is implied by Kahn and is composed of three types of government involvement in the economic system: (a) those political activities that cause government entities to be co-participants with business and consumers as producers and users of economic resources; (b) governmental control or direction of certain economic decisions by selected industries (e.g., public utilities); and (c) that range of statutory, administrative and common law that attempts to encourage, constrain or facilitate operational aspects of the private market economy. Within this definitional framework it is clear that regulation permeates the organization and operation of the U.S. food system to a considerable degree.

U.S. Food System Regulation

The U.S. food system has a unique organizational structure. A concentrated array of input manufacturers sell to a less-concentrated distribution level, and they provide production supplies to a relatively atomistic structure of farmers. In terms of vertical input-output flow, commodities produced by hundreds of thousands of farmers enter into an increasingly concentrated series of markets, finally to reach millions of highly-decentralized consumers.

---

[1] This lack of agreement is amply demonstrated by a comparison of the articles by Shaffer and by Gardner in this special issue of the *American Journal of Agricultural Economics*.

[2] Presumably, this broad definition of the term would encompass the entire set of economic functions of government as presented in principles texts: "(1) providing the legal foundation and social environment conducive to the effective operation of the price system, (2) maintaining competition, (3) redistributing income and wealth, (4) adjusting the allocation of resources so as to alter the composition of the national output, and (5) stabilizing the economy, that is, controlling unemployment and inflation caused by the business cycle and promoting economic growth" (McConnell, p. 102).

Within this economic subsystem are not only millions of business firms and consumers, but governmental units (federal, state and local), which play participatory roles as holders of vast quantities of natural resources and as buyers and sellers of raw farm products and foodstuffs. Data from 1974 (USDA) show that 40% of the total U.S. land area was under federal, state, and other public ownership. This public land holding was not merely in the use form of parks and forests, but included, in addition to forests, 1% of the cropland, 33% of the pasture and rangeland, and 84% of special use and unclassified lands, such as tundra, swamps and that used for military bases. Largely through the Commodity Credit Corporation, the federal government is a major purchaser of raw farm products, not merely for the purpose of farm price stabilization but as an input to domestic and foreign assistance programs. Federal, state and local governments also purchase processed and packaged foodstuffs to satisfy several domestic and foreign assistance programs.

While the term "public utility regulation" is rarely applied to agriculture, it is clear that the U.S. food system has most of the attributes of a public utility and the several price and income policies of the federal government have become increasingly directed not only to such common variables as rate making (prices) and entry, but to the quality and quantity of food available for nutritional needs (Houthakker). The public utility character of the U.S. food system is put in bold relief by consideration of the collective bargaining alternative for farmers (Geyer). Can farmers, through collective action, be permitted to produce and sell any quantity and quality of food at prices advantageous to them, without the welfare of consumers being protected by government?

More than in most industry groupings, the U.S. food system is monitored, constrained and facilitated in its organization and operation by a highly complex set of statutes, administrative rules and common law pronouncements at all levels of government (Grant, 1978). At the federal level, land and water use constraints, environmental laws, farm labor policies, and agricultural finance programs stand out as intervention examples directed to the regulation of agricultural resource use. Policies that limit business organization alternatives, and those that foster and constrain agricultural cooperation as well as other forms of collective bargaining exemplify governmental influences on U.S. food system organization. Special tax policies and a range of programs designed to expand the demand for farm products, assist disadvantaged consumer groups, and foster international trade are regarded as central to U.S. farm policy. Beyond this, a substantial set of rules administered by several federal agencies attempts to foster competition and protect consumers, farmers and agribusinessmen in the name of health, contractual justice and economic protection (Burke).

The conclusion is clear. Regulation of the U.S. food system represents all of the aspects of regulation economics set forth earlier: government participation, public utility direction, and operational rules. From a review of the literature it is clear that the words "agricultural policy" have not meant the full range of regulations espoused here.

From Agricultural to Food Policy

During the past two decades the phrase "agricultural policy" has been changed to "agricultural and food policy" and that set of statutory, administrative and common law relating to agricultural policy has expanded to include a wide range of issues stretching from the problems of rural proverty and environmental pollution to international trade and development, to antitrust and market regulation, to the protection of the consumer from misinformation about food products and from unsafe or poor quality food. This broader view of the regulation of the U.S. food system has encouraged agricultural economists to expand their analyses away from the mere consideration of how to enhance the income and welfare position of the American farmer, and to consider the external effects and interrelationships of those policies in terms of other segments of the economy. This broader view also has brought forth an increased number of demands by policy analysts that agricultural economists develop a comprehensive and internally consistent food policy in the years ahead. Those agricultural economists who wish to respond to this plea increasingly have faced the realization that the regulation of the food system is so extensive that it almost requires specialized legal training and study to begin to comprehend the magnitude and interrelationships of the pertinent law.

Food Regulation Education

No single document, set of volumes or journal permits the interested agricultural economist access to that full subset of the law that pertains to the regulation of the U.S. food system. Because of this, agricultural economists not only continue to approach economic problems in a piecemeal fashion; they are also limited in their vision as to possible legal solutions.

Economic analysts, like others, have become increasingly specialized, not only in terms of the problems addressed, but also with regard to the methodology employed.

Academic agricultural economists have long been methodologically oriented rather than problem oriented in their studies, and they have been particularly noted for using fashionable approaches. A successful analytical method that gains academic respectability is frequently replicated to the point of intellectual exhaustion while social problems are left unaddressed or under-addressed. We are fast approaching a real world of problems that can no longer be left to lawyers and other professionals to resolve without the aid of economic analysis.

A Regulatory Paradigm

Nearly 20 years ago a research approach which would serve as an orientation for studies of the marketing and pricing of food products was suggested to agricultural economists (Clodius). This paradigm of analysis was captured by the phrase "market structure analysis," which professed to study the relationships among a group of variables classified under the headings of structure, conduct, and performance. This analytical approach had a history of uses in industry, legal analysis and economics. It achieved a level of academic respectability and offered potential as an approach to a wide range of significant economic questions. Numerous studies were made by agricultural economists using this approach (Dahl). Unfortunately the research that resulted came under attack as being essentially descriptive, lacking in analytical content, and having limited social impact (Farris).

In my view these assessments did not lessen the power of the investigative approach but rather demonstrated that it had been sorely misused. Most of the market structure studies completed did little more than describe the number and size distribution of firms engaged in various market activities, and they appeared to be conducted without respect to a problem focus. In addition, economists encountered substantial difficulties in conceptualizing and quantifying conduct and performance variables. Following the attacks against the studies by respected agricultural economists, researchers tended to abandon this approach in favor of more fashionable methodologies. Accordingly, most of the recent developments in market structure analysis have come from industrial organizational economists and those involved with antitrust problems (Helmberger).

Normative Market Structure Analysis

Even if the market structure approach had succeeded it could have been argued that the sequencing of the trilogy was reversed and lacking in terms of problem identification. Rather than descriptively seeking the structure of markets or industries so that conduct and performance hypotheses can be positivistically tested, the research method might well have yielded more acceptable results if the analysis had been more normative in nature from the start.

A normative market structure analysis would presumably begin by identification of a performance problem, leading to a study of structure and behavior as an explanation for the existence of the problem. For example, a normative market structure study might begin with the observation that industry profits are high relative to other industries and would proceed in the development of hypotheses that included structure and conduct variables (as well as others) that would help explain this disparity.

Such a normative market structure analysis, however, would be lacking unless attention were paid to how a disparate profit situation could be corrected. Unlike legal scholars, economists (especially those in the academic world) tend to limit their normative studies to the mere identification of explanatory forces rather than to continue seriously in their research by offering analyses of alternative remedies that might be used to resolve the perceived problem.

Regulatory Remedies

As might be expected, legal scholars pay considerable attention to the remedy of conflict or problem situations. These remedies may be pecuniary, punitive or equitable in character but they are designed to resolve immediate and long-range problem situations by economic and political sanctions.

While the law of remedies usually is studied in terms of micro-decision making situations, a corollary (and analogous) set of remedies exists with respect to macro-legal problem situations. These remedies are principally economic and political in character and represent alternative means by which problems can be resolved. A number of regulatory alternatives were set forth in a recent Senate report devoted to the study of federal regulation (U.S. Congress). They included such options as deregulation, establishment of performance standards, regulation of information, economic incentives, and various subsidies. There are other regulatory alternatives as well.

Regulation economics, in terms of the previous discussion, is a form of normative economic analysis that includes an analytical consideration of policy remedies of problem situations. It is not limited to the use of expanded or reordered market structure analysis, but has as its distinctive character its orientation to macro-legal remedies of perceived problems.

In terms of the market structure analysis illustration, a paradigm for regulation economics would include four sets of variables: performance, structure, conduct, and regulation. The sequencing of the analysis might take on several forms but would always include a problem statement as well as a study of alternative regulatory options to aid in problem solution. If, for example, the problem was perceived as relatively high profits in an industry, the analysis would not only be directed to why these profits exist and to whether or not they are justified, but also would extend to consideration of regulatory alternatives that could be employed in an effort to reduce profits to more acceptable levels.

Government and Academic Research

In the categories of economic inquiry attributed to regulation economics it is easy to recognize a significant portion of the work of food research economists in the federal establishment and especially in the U.S. Department of Agriculture.

While we may recognize regulatory economics as something that we practice as government researchers, it appears from my review of the literature as something not often practiced by academic agricultural economists. Part of the reason for this, clearly, is that government economists perform their research within the milieu of the law and its administration, while academic economists are free to study questions and methods without being so fettered. It goes without saying, perhaps, that agricultural economists at academic institutions frequently have been admonished for not dealing with the most pressing agricultural issues addressed in governmental circles. In some ways this separation has reaped conceptual and methodological benefits. But in other ways it has produced a set of research results that are sometimes trivial or redundant.

Increased efforts of academic agricultural economists to engage in regulatory economic analysis may help not only to bolster a sagging research image, but also to provide a merging of concerns between academic and governmental economists. This can only be achieved through a concerted effort to educate academic economists as to the regulations that pertain to the food system. For this effort to have an impact, a willingness on the part of government agencies to accept advice and criticism is needed. Perhaps even more important than education and administrative openness is knowledge of the analytical techniques and theoretical analyses that might be employed in addressing regulatory questions.

Methods of Regulatory Analysis

Consideration of the role of the economist in the regulatory matters of government involves recognition that "public economic policies are not, and cannot be framed on the basis of 'purely economic' considerations alone" (Kahn, p.14).

We are, at once, confronted by the practical question: What guidance can economics provide legislators, administrators and judges in framing, applying, and enforcing policies involving government participation, direction and facilitation of private sector competition? Consider the answers provided by Kahn.

The answer to this question combines the two quite distinct purposes of economics—science and prescription. There is nothing unusual about this double motivation; it involves ambivalence only when we fail to keep clearly in mind which of the two purposes we are at any time serving, and in which of our two roles, physician or scientist, we are acting. As for the first, there must be very few professional economists who were not moved to enter that gloomy profession (no matter how far they may later have gone astray) by a belief that economic problems bulk large among the many vexations of human existence in society, and by a hope that the application of goodwill, intelligence, and professional expertise to the formulation of public policy could make an important contribution to the improvement of the human condition.

But if such an inquiry is to be conscientious, its scope and method must be rigidly scientific as well. The economist who asks a politician "Won't you let me advise you on your legislative program?" deserves only another question in response: "What do you *know*?" And only the economist who can answer "Well, I can tell you that if you pass a law that says such-and-such, these are the things that will probably happen," or "If you do nothing about such-and-such, this is what will probably happen," deserves to have his offer taken seriously.

This is not to argue that economists have no other function in government than to serve as technical assistants to politicians. As we have already suggested, formulating public policy can never be a job for the scientist alone. In the last analysis, deciding what *should* be done can never be accomplished only with the help of the type of information that says "If you do A, then B will follow." And if it follows from this truth that economists cannot, *as scientists*, presume to settle the ultimate issues of public policy, it also follows that there are no *other* scientists who can presume to do so either. If framing public policy requires in the last analysis the *art* of the politician or philosopher, this is an art that the economist may be better equipped than anyone else to acquire and to practice within his own domain: who can have given more thought than he to the ultimate ethical and political implications of alternative public economic policies?

Economists have a particular advantage when it comes to taking a direct role in the regulatory process. The job is an extremely technical one and becomes more so each year. It used to be done almost exclusively by lawyers and politicians, with accountants and engineers as assistants. But for decades there has been great and increasing dissatisfaction with their performance. One important criticism has been that they were behaving too much like lawyers and bookkeepers—excessively concerned with proper administrative procedures, the balancing of equities, and the measurement and covering of accounting costs—and too little like economists—paying practically no attention to things such as marginal cost, elasticities of demand, or to the dynamic conditions of innovation and growth. For these and other reasons that will appear later, economists have been drawn more and more into the process, bringing with them their own esoteric terminology and tools; the lawyers that have failed to seek their direct cooperation find they cannot understand what their opponents' witnesses are saying (pp. 14–15).

Economic Decisions by Government

It was argued earlier that U.S. local, state and federal governments have functions of resource management and product purchasing and selling similar to those of other food economic sector participants. The major difference presented by government participation is the oft-noted variation in its objective functions as compared to businesses and consumers. Presumably, government engages in economic activities not to maximize short- or long-run profits, but to enhance public welfare, to assure economic stability, and to otherwise conduct its foreign and domestic policies.

There is a notable lack of published economic modelling and analysis as to this type of public decision making. But it has been addressed in legal literature under the rubric of "economic theories of regulation."

> Two main theories of economic regulation have been proposed. One is the "public interest" theory, bequeathed by a previous generation of economists to the present generation of lawyers. This theory holds that regulation is supplied in response to the demand of the public for the correction of inefficient or inequitable market practices. It has a number of deficiencies that we shall discuss. The second theory is the "capture" theory. This theory holds that regulation is suppled in response to the demands of interest groups struggling among themselves to maximize the incomes of their members (Posner, pp. 335–336).

Much of the rationale for government resource management and the trading of agricultural and food products is part of the public Congressional Record, but agricultural economists need to do systematic studies of administrative decision making. A series of studies by the American Enterprise Institute relating to nonagricultural industries and other economic activities illustrate the type of analysis needed for the food system.[3]

[3] American Enterprise Institute (Selected Series), Washington, D.C.: Campbell, Rita Ricardo, "Food Safety Regulation," AEI-Hoover Study 12, Aug. 1974. Helms, Robert B., "The Economics of Environmental Quality," National Energy Study 2, July 1974. Hite, James C., Hugh H. Macaulay, James M. Stepp, and Bruce

Public Utility Regulation

Federal price programs for agriculture represent the key type of rate-making regulation so central to public utility economics. With target prices associated with average cost of farm production, the issues of marginal versus average cost pricing are muted by the existence of an atomistic farm structure. But the economic price-discrimination basis for certain market orders opens up the rate-making issue in terms of producer and consumer costs and benefits. Some of the recent work by Buxton exemplifies the type of regulatory analysis that can and should be undertaken by agricultural economists in the years ahead (Buxton).[4]

Market Regulation Analyses

The substantial array of agricultural and food statutes, administrative rules, and court decisions require systematic analysis by agricultural economists. At least four types of studies can be undertaken, most of which employ traditional microeconomic models and quantitative methods: (a) pre-legislation research; (b) post-legislation research; (c) administrative agency studies; and (d) cumulative impact investigations.

Economists should and do make important contributions to the development of rule making by legislative and administrative bodies. Stigler, in a plea to scholars, emphasizes the importance of this type of research:

> Let us pause for a moment to discuss the difficulty of disentangling and measuring the effects of an economic policy. Many lawyers and some economists will deny that it is possible, for example, to separate the effects of the S.E.C. [Securities and Exchange Commission] review of stock prospectuses from the effects of higher taxes, more stable national growth, accelerating innovation, and a thousand other circumstances that distinguished the 1960s from the 1920s. I would remind these doubters that if we cannot measure the effects of policies, the society is incapable of rational behavior—rational behavior is behavior appropriate to the ends in view, and means cannot be appropriate if their effects are unknown. The fundamental reply to the doubters, however, is that we can isolate the effects of policies with substantial and improving precision. My study of the S.E.C. review of stock prospectuses, which reached the conclusion that the review had not improved the experience of purchasers of new stock issues, was much criticized by the S.E.C. defenders. Even the critics, however, accepted my general line of economic analysis, and almost all disinterested students accept the conclusion that the S.E.C. review has not made a large difference. With further study the conclusions can be made more definite and more reliable, but techniques of economic analysis are already available to form a useful estimate of the effects of most economic policies (Stigler, 1973, pp. 7).

No single or simple methodology is employed regularly to conduct pre-legislation economic research. Clearly, among the most popular techniques are various uses of cost-benefit analysis, a set of concepts and techniques that have become a regular part of the "tool-kit" of the agricultural economist (Westfield). Another obvious methodology employed is the use of forms of input-output analysis, especially where the tracing of external impacts of proposed policies is important (Rose). In general, the particular method of analysis must be tailored to the rule proposed and the interests perceived (Petersen).

Post-legislation research involves a "post-mortem" consideration of the effects of a rule once it is in effect. In essence, it could be regarded as a follow-up analysis of what actually happened as a result of a new rule in contrast to the pre-legislation study of what might happen. This hindsight study is or should be a crucial part of continued legislative and administrative efforts to assess the original action. Unfortunately, less published work illustrating this research approach is available than its importance implies. Part of the reason for this, or course, is the difficulty of sorting out the effect of a policy as part of an array of influencing factors over time.

It seems reasonable to suggest that pre- and post-legislative studies should be viewed by economists together as a complete analysis so that methods might better be devised to isolate policy effects. This represents a challenge not only to government economists, but also to administrators who need to become aware of the need for this more comprehensive approach.

The study of administrative agency behav-

Yandle Jr., "The Economics of Environmental Quality," Domestic Affairs Paper 5, Sept. 1972. Lilley, William and James C. Miller, "The New 'Social Regulation,'" Reprint 66, May 1977. Miller, James C., "Regulatory Reform: Some Problems and Approaches," Reprint 72, Aug. 1977. Moore, Thomas Gale, "Trucking Regulation," AEI-Hoover Policy Study 18, Jan. 1976. Peltzman, Sam, "Toward a More General Theory of Regulation," Rep. 71, July 1977. Posner, Richard A., "Regulation of Advertising by the FTC," Evaluative Studies 11, Nov. 1973. Smith, Robert Stewart, "The Occupational Safety and Health Act," Evaluative Studies 25, Jan. 1976. Weidenbaum, Murray L. and Robert DeFina, "The Cost of Federal Regulation of Economic Activity," Reprint 88, May 1978.

[4] See the article by Buxton in this special issue.

ior now is a more important part of economic and legal literature than ever before (Russell and Sheldon). This type of analysis includes attempting to specify the utility functions of administrators for insight into their decision making. Aspects of this function include (but are not limited to) assurance of the administrator's post-regulatory agency future retention of a political coalition, his or her own views of what is right and wrong, and reputation with peers and associates.

While the subject of "what makes the USDA tick" is frequently encountered in "coffee" talk or popular (and sensational) articles and books, relatively little scholarly effort has been expended to understand the political pressures and internal workings of the agencies that administer food and agriculture policy.

Recently, interest has developed in the final category of market regulation research, the cumulative impact of a group of rules that impact upon various dimensions of the food economy. This type of analysis is illustrated by various attempts to answer the question of what is the dollar cost of regulating a segment of the economy. The problem with this type of research, as with cost-benefit analysis generally, is the appropriate specification of the direct and indirect costs involved and whether a meaningful quantitative appraisal of the benefits can be obtained. This kind of research also suffers from the difficulties encountered by the analyst in determining the causal relationships and levels of influence they represent. Also of substantial significance is the issue of whether stated rules are, in fact, enforced.

Conclusion

Agricultural economists, because of their rich history in applied, normative economic analysis, have the opportunity to make substantial intellectual contributions to regulation economics in the years ahead. In so doing, they also have the chance to be much more influential than they have been in policy-making processes by government at all levels.

> There are known aspects of our society which most of us wish to improve, and new and different imperfections will continue to appear. If we seek to correct these various deficiencies without knowing how legal systems work and what effects they actually achieve, we shall achieve improvements only by sheer chance. We shall often embark upon programs to aid paupers that further impoverish them. The law and economics of public policy now poorly serve, but can surely be brought to serve powerfully, our social conscience (Stigler, 1973, p. 2).

References

Bronfenbrenner, Martin. "A Middlebrow Introduction to Economic Methodology." *The Structure of Economic Science*, ed. S.R. Krupp, pp. 5–24. Englewood, N.J.: Prentice-Hall, 1966.

Burke, Timothy J. and Dale C. Dahl. *Federal Regulation of the U.S. Food Marketing System*. Unpublished manuscript. Dep. Agr. and Applied Econ. University of Minnesota, 1979.

Buse, Reuben C. and Daniel W. Bromley. *Applied Economics: Resource Allocation in Rural America*. Ames, Iowa: Iowa State University Press, 1975.

Buxton, Boyd M. *Social Cost of the Dairy Price Support Program*. Dep. Agr. and Applied Econ. Staff Paper 73-34, University of Minnesota, 1973.

Clodius, Robert L. and Willard F. Mueller. "Market Structure Analysis as an Orientation for Research in Agricultural Economics." *J. Farm Econ.* 43(1961):515–553.

Dahl, Dale C. *Market Structure Analysis and Research*. Dep. Agr. and Applied Econ. Staff Paper P69-16, University of Minnesota, 1969.

Farris, P.O., ed. *Market Structure Research*. Ames, Iowa: Iowa State University Press, 1964.

Geyer, L. Leon and Dale C. Dahl. "Collective Bargaining for Farmers." *Minnesota Agricultural Economist*, no. 599(1978).

Grant, W.W. and Dale C. Dahl. *Bibliography of Agricultural and Food Law: 1960–78*. University of Minnesota Agr. Exp. Sta. Bull. 523, 1978.

——— *Bibliography of Economic Regulation with Special Emphasis on Agriculture and the Food System, 1960–1979.* Unpublished manuscript. Dep. Agr. and Applied Econ., University of Minnesota, 1979.

Helmberger, Peter, Gerald R. Campbell, and William D. Dobson. "Organization and Performance of Agricultural Markets." Unpublished manuscript, proposed as part of *A Survey of Agricultural Economics Literature*. Dep. Agr. Econ. University of Wisconsin, 1979.

Houthakker, H.S. "Do We Need a National Food Policy?" *Amer. J. Agr. Econ.* 58(1976):259–269.

Kahn, Alfred E. *The Economics of Regulation: Principles and Institutions*. New York: John Wiley and Sons, 1970.

McConnell, Campbell R. *Economics: Principles, Problems, and Policies*. New York: McGraw-Hill Book Company, 1975

Peltzman, Sam. "Toward a More General Theory of Regulation," *J. Law and Econ.* 19(1976):211–240.

Petersen, H. Craig. "An Empirical Test of Regulatory Effect." *Bell J. Econ.* 6(1975):111–126.

Posner, Richard A. "Theories of Economic Regulation." *Bell J. Econ.* 5(1974):335–358.

Rose, Adam. "A Simulation Model for the Economic Assessment of Alternative Air Pollution Regulations." *J. Reg. Sci.* 17(1977):327–344.

Russell, Milton and Robert Sheldon. "A Model of Regulatory Agency Behavior." *Pub. Choice.* 20(1974):47–62.

Russell, Stuart H. "Agricultural Law—Federal Administrative Procedures." *S.D. Law Rev.* 19(1974):603–621.

Stigler, George and Claire Friedland. "What Can Regulators Regulate: The Case of Electricity." *J. Law and Econ.* 5(1962):1–16.

Stigler, George J. "The Law and Economics of Public Policy: A Plea to the Scholars." *J. Legal Stud.*, no. 1(1973), pp. 1–12.

———"The Theory of Economic Regulation." *Bell J. Econ.* 2(1971)3–21.

Taylor, Henry C. and Anne Dewees. *The Story of Agricultural Economics in the United States, 1840–1932.* Ames, Iowa: Iowa State College Press, 1952.

U.S. Congress, Senate, Committee on Governmental Affairs. *Framework for Regulation. Study on Federal Regulation,* vol IV, Doc. 96-13, 95th Congress, 2nd session, Dec. 1978.

U.S. Department of Agriculture. *1978 Handbook of Agricultural Charts*. Agr. Handbook no. 551, Nov. 1978.

Westfield, Fred M. "Methodology of Evaluating Economic Regulation." *Amer. Econ. Rev.* 61(May 1971):211.

Pre-Regulation Research: The Triumph of Policy Analysis

Thomas P. Grumbly

Washington has a way of taking simple, even elegant truths and transmuting them into intellectual mush. In their moment of triumph, ideas are quickly sucked into the maw of the executive branch and never heard from again. When I saw the title of this paper in the conference brochure, I knew two things: first, policy analysis had finally triumphed in domestic agencies; second, its transformation into ''pre-regulation research'' indicated that analysis was about to be turned into an endangered species.

I want to talk today partly about the triumph of analysis in regulation, but mostly about the danger signals that could threaten its existence—signals that are more serious than unfortunate terminology. I want to do this against a brief historical backdrop of analysis that may help you understand the urgency with which I deliver my message.

Policy analysis is the reincarnation, in my view, of the old discipline of political economy. It attempts to amalgamate political science, economics and other disciplines to make the whole more than the sum of the parts. In doing this, it represents the best of the Enlightenment tradition that commands us to take hold of our futures and mould them by our reason. It is not clear, however, that analysis is in an equilibrium situation. The drive for specialization and the conflict of world [illegible]

For the moment, however, analysis has clearly triumphed. The evidence is abundant: Executive Orders demand that analysis be done; policy study groups spring up all over town; legislation is introduced to ensure that analysis is enshrined in statute. The questions now are: how do we make it work and how can we make it stick?

I think these questions are best addressed by looking at some emerging problems. Some are endogenous to the various policy analysis systems—we can see them happening as analysis is installed as a result of either Executive Orders or agency fiat. Others are, not surprisingly, exogenous, and have more to do with the intrinsic nature of the federal system. Solutions to both sets of problems must be reached before analysis can be said to be more than a fleeting event on the public stage.

Problems Inherent in Policy Analysis

The analytical systems currently being installed in regulatory agencies bring at least four difficulties with them: (*a*) analysis, believe it or not, is not easy to explain; it is not intuitively obvious to the casual observer; (*b*) the method of implementation threatens to glorify process over substance; (*c*) the modes of policy analysis—particularly cost/benefit anal-

informed decisions is lacking; documentation often does not exist. The temptation of the analyst to be nonanalytical can become unbearably strong.

In the same way that one cannot tell people how to do analysis, neither can one legislate it without running the risk of trivializing an important subject. If the reasons for analysis are not carefully explained and digested—and, more importantly, if incentives are not extant to produce good analysis—the executive branch will produce a blizzard of paper and not much else. This is the harsh lesson of Programming, Planning and Budgeting (PPB) of the mid-1960s. If you will recall, President Johnson ordered this particular brand of analysis in all domestic agencies (not just regulatory agencies). It fell of its own weight. Analysis survived that fiasco, if only barely, and we must take care to nurture and to push only as fast as the bureaucracy can bear.

This brings me to perhaps the most important internal conflict within impact, preregulation, or policy analysis: the philosophical battle that pits, in essence, proponents of marginal utility theory on one side and principled activists on the other. I suspect that most of us here resolved the problem for ourselves after we took Economics I. The concepts of marginal utility, opportunity cost and the like teach that we have choices in the world for our scarce resources and that nothing is absolute (except perhaps the concept of balance inherent in the teachings themselves). For various reasons, other intellectual and social traditions in this country view this economic man as unprincipled man—as man willing, for example, to sell his neighbor's health in return for a few cents less on his utility bill. This conflict becomes increasingly intense as always scarce resources become scarcer because of inflation or other reasons.

I believe that this battle between balance and principles will be the hallmark of the last twenty years of this century, as Americans are forced to adjust to a world in which they control fewer of the means of production. As an analyst, I am convinced that we must find some way to reconcile the two camps, lest analysis be charged (perhaps justifiably) with sacrificing the democratic values that distinguish America from the world's tyrannies in the name of rationality. On the other hand, we must remember Alexander Hamilton's admonition in the first *Federalist Paper:*

> It will be forgotten, on one hand, that jealousy is the usual concomitant of violent love, and that the noble enthusiasm of liberty is too apt to be infected with a spirit of narrow and illiberal distrust. On the other hand, it will be equally forgotten, that the vigour of government is essential to the security of liberty; that in the contemplation of a sound and well-informed judgment, their interest can never be separated; and that a dangerous ambition more often lurks behind the specious mask of zeal for the rights of the people than under the forbidding appearance of zeal for the firmness and efficiency of government. History will teach us that the former has been found a much more certain road to the introduction of despotism than the latter, and that of those men who have overturned the liberties of republics, the greatest number have begun their career, by paying an obsequious court to the people, commencing Demogogues and ending Tyrants (Hamilton, pp. 5–6).

Efficiency, then is no vice; my concern is that it not become the principle used by demogogues to exploit a people that is losing its wealth. In other words, analysts must choose their patrons carefully.

A final, and very practical, endogenous problem for analysis is the need for staff analysts—bureaucrats—to do analysis. Despite the nearly level nature of full-time federal employment over the last ten years, most Americans outside Washington perceive the federal government as bloated. They are, of course, at least half right. We obviously have numbers of people who really have outlived their professional usefulness. This should not obscure our need, however, for more first-rate people to do the kind of analytical work that line managers often do not have the time for or the interest in. I was reading the *Washington Post* recently and spotted a comment by a man in a little town in Missouri, who, when asked by the reporter what he thought of the problems that confronted the world said, "There's plenty of people to worry about them things, so I just go about my business and hope they do a good job." So say we all, but where are those people in my agency who have the time to think and write?

Other Problems Facing Policy Analysis

Earlier, I promised to discuss some other problems within the federal system that will present obstacles to the implementation triumph (as opposed to conceptual) of analysis, particularly in regulatory agencies. In the main, I think these are three: (*a*) the fear, even

by bureaucrats, of increasing complexity that further dilutes personal responsibility; (*b*) the trend in government to make more decisions at upper levels coloring an already difficult situation with class overtones; and (*c*) the evident split in health regulatory agencies between policy and science.

As we approach 1984, the spectre of George Orwell looms ever more threatening on the horizon, and people fight to keep the society simple and resist the kinds of perversities that Orwell predicted. Policy analysis is seen by many people as merely another new vocabulary "complexifying" an already-mysterious world. People are wary of the cold-eyed analyst; they conjure up pictures of a future dominated by a reason that seems to exclude passion and politics from consideration. More particularly, the growth of policy studies staffs in both cabinet agencies and the Executive Office of the President multiplies the number of veto points in an already-burdened system. This further depersonalizes decision making and can, if not carefully watched, produce an *ennui* in the operating arms of government that will defeat the purposes of doing analysis in the first place.

Related to this first problem, but perhaps more significant, is the increasing tendency of policy officials to make more and more decisions—often based on the analysis presented to them. This is fine in principle, resting on a widely accepted, and, I think, legitimate notion that career officials fundamentally should recommend, but not unilaterally initiate, new policy. However, by permitting policy officials to exercise greater independence, analysis can exacerbate the "only I know" elitism that many new officials enter the government with. Instead of fostering trust, analysis can erode it and introduce a new kind of authoritarian attitude into government that may be just as bad as the helplessness heretofore induced by being at the mercy of career officials.

Finally, and most parochially, policy analysis is being introduced in regulatory agencies at the same time that the scientific community (and here I am thinking mostly of the National Academy of Sciences) is beginning to question the connections between science and policy. Should the two be disconnected? Should scientific testing, particularly chronic toxicology, be carried out by institutions that do not need to bear the policy responsibility for decisions? In the current system, policy analysis and science are clearly in a symbiotic relationship, as economics and politics attempt to define questions for study, press for alternative solutions, and so on. The scientist cannot be disconnected now from policy officials, although each must have a clearly-defined role. This causes tension, but it is often useful in guiding scientific inquiry along paths that create useful near-term knowledge. Any departure from this system might thoroughly change the environment within which analysis is carried out and consequently alter the requirements.

The Search for Solutions

Solutions to these problems are not easy to generate. I am not going to try to solve each and every problem, but merely to suggest a range of things that could be done to improve the climate for analysis.

First, we must apply the principles of economics to our choice of analyses. We can neither work our good people to death, nor use them on issues that are minor. The urge to require analysis on all decisions is great, but we must resist it. Rule one then is that more analysis on fewer issues guarantees the best use of resources.

Second, we must somehow strike a *detente* between the policy and career officials of this government. Analysis must not be used as a weapon by policy officials to raise decisions higher than their importance deserves. If analysis is seen to represent and symbolize mistrust, it will die. Rule two might then be stated: Make policy analysis a cooperative intellectual endeavor between short-timers and long-timers.

Third, we must remember that analysis is a means to an end, and not an end in itself. If analysis is perceived to symbolize delay, it will be attacked and, I believe, ultimately demolished from both the right and the left. Rule three then is only to do analysis on issues that you are prepared to make decisions on.

Finally, rule four is that we must only promise what we can deliver. We cannot say that policy analysis by itself will make regulation more efficient, or government less intrusive. These problems are too heavy a load for any single system. What we can say is what scholars have been telling us for many a year: Analysis can clarify objectives and help us move

Post-Regulation Research: Milk Marketing Order Regulations

Boyd M. Buxton

The dairy industry represents a major part of the U.S. food system. In 1977 consumer expenditures for fluid milk and manufacturing dairy products reached $27.4 billion and represented 12.6% of the consumers' total food dollar.

Questions are being raised about the impact of the federal milk marketing order program which directly regulates the handling and farm-level pricing of about 65% of all milk produced in the United States. The program has been in existence for over forty years and has played an integral and pervasive part in shaping the U.S. dairy industry.[1] Before any changes are made in the program, it is important to untangle and understand the complex economic relationships involved in order to evaluate the continued need for all or part of these regulations. This paper is an example of post-legislative research designed to help evaluate a long-standing set of regulations.

Generally, the milk order program is not well understood. Some research results have been very controversial, and points of view on the program vary widely.[2] Some argue that the program does not meet the stated goals outlined by Congress (Masson and Eisenstat) while others argue that the goals have been achieved and the public interest served with a minimum amount of government regulation (Forest). Some studies have attempted to measure the social costs of the program (Ippolito and Masson, MacAvoy) or alternative pricing policy modifications of the program (Buxton 1977, Dobson and Buxton). Other studies have considered the economic impact of alternative pricing policies under milk orders (Hallberg, Fallert and Buxton).

This paper is divided into three parts. The first part reviews the major regulatory procedures and goals of the federal milk marketing order program. It further develops the economic rationale on how the regulations achieve those goals and reviews the major benefits usually ascribed to milk orders. The second part of the paper contains a discussion of the major economic impacts of milk orders while the third part contains some conclusions and policy implications.

Federal Milk Marketing Orders

On 1 January 1979, there were forty-seven federal milk marketing orders in the United States. These orders only regulate Grade A milk, which is produced under more stringent sanitary conditions than Grade B milk. Milk must be Grade A in order to be used as a fluid beverage (fluid milk) while manufactured dairy products can be made from either Grade A or B milk.

There are two major regulations used in all federal milk marketing orders: (*a*) classified pricing whereby milk dealers (handlers) are required to pay different prices for the Grade A milk they buy depending on how they use the milk; and (*b*) pooling all revenue from the sale of Grade A milk at the different use prices from which a uniform (blend) price to be paid Grade A farmers is calculated.

Classified Pricing

Federal order regulations require handlers who buy Grade A milk from dairy farmers or associations of dairy farmers and who distribute it in the specified market area to pay at least minimum prices set under the order for the milk according to how the milk is used. If the milk is used in fluid products such as whole

---

Boyd M. Buxton is an agricultural economist, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, St. Paul, Minnesota.

The author acknowledges the comments and suggestions of Jerome Hammond, Martin Christiansen, Richard Fallert, James Miller and David Banker. The views expressed in this paper do not necessarily reflect the official views of the USDA or ESCS.

[1] The Agricultural Marketing Agreement Act of 1937, as amended, provides the legal basis for the federal milk marketing order program (Ward).

[2] For example, see the exchange of ideas between the U.S. Justice Department and the U.S. Department of Agriculture resulting from the original report entitled "The U.S. Justice Department Report on Milk Marketing" (U.S. Department of Justice, 1977, 1978/USDA, 1977).

milk, skim milk, low-fat milk, and milk drinks, it is designated as Class I and receives a Class I price.

If the milk is used in manufactured dairy products such as butter, dry milk, and nonfat dry milk, it is designated Class III milk and receives a Class III price.[3]

The same Class III price is used in most federal orders and is set equal to the average price that manufacturing plants pay per 100 pounds of Grade B milk (f.o.b. plant) in the Minnesota-Wisconsin area (often referred to as the M-W price). This price is determined by supply and demand conditions in the manufacturing milk market and moves up and down as supply and demand conditions in the market vary. A floor is effectively placed under this price by the operation of the price support program as the government stands ready to purchase dairy products in amounts needed to keep it from falling below the support price.[4]

A minimum Class I price is separately determined for each federal order by adding a Class I differential to the M-W (Class III) milk price. Under present pricing policy, the minimum Class I price in federal orders east of the Rocky Mountains can be approximated by adding to the M-W price 90¢ plus 0.15¢ for each mile the specific order area is located from Eau Claire, Wisconsin. For example, the minimum Class I price in Southeastern Florida market order is set at $3.15 above the M-W price (90¢ plus 0.15¢ times the approximately 1,500 miles the order is from Eau Claire, Wisconsin).

Pooling Returns

A second major regulation of federal orders requires that all payments for regulated Grade A milk in the different use classes be pooled. A uniform (blend) price representing the average value of all Grade A milk sales in the order is calculated and used as a basis for paying dairy farmers or their cooperative associations. In order to qualify for the pool, dairy farmers or their cooperative association must ship designated proportions of their milk to the fluid market for Class I use. The pooling regulation is a mechanism that allows all dairy farmers producing Grade A milk in a given market to receive a comparable price regardless of how their milk is used. Before federal orders were established in 1937, milk cooperatives had instituted similar pricing and pooling programs. However, the depression conditions made such programs difficult to operate without formal government regulation.

Goals of Federal Milk Orders

The major goals commonly ascribed to federal milk marketing orders as presently administered are reflected in the following list:[5] (*a*) to promote orderly marketing conditions for milk produced by Grade A farmers; (*b*) to set minimum prices consistent with supply and demand conditions and to assure consumers an adequate supply of fluid milk year-round; (*c*) to administer and supervise the terms of trade in deficit milk markets in such a manner as to equalize the market power of buyers and sellers and promote constructive competition; (*d*) to improve the income situation for Grade A dairy farmers.

An overriding objective is that milk orders are to be administered so as to be in the public interest. The above goals lack clarity in meaning by using terms such as "orderly marketing" and "adequate supply." These terms must be more precisely defined in order to provide a better understanding of what milk orders are to accomplish.

The term "orderly marketing" usually is associated with stabilizing fluid milk prices, providing secure and dependable markets for individual Grade A dairy farmers producing milk primarily for the fluid market, and promoting constructive competition by improving the balance of market power between farmers and handlers. "Adequate supply" is usually associated with maintaining a reserve of Grade A milk on a seasonal, weekly, and daily basis that can be drawn from when the Grade A milk supply is tight relative to fluid demand. Such a reserve would eliminate unusually high prices and possible shortages.

[3] Milk used in certain soft manufactured products is designated Class II and receives a Class II price about 10¢ above the Class III price. Conceptually, these two use class designations can be treated as one.

[4] The government presently supports the U.S. manufacturing milk price, which is normally about 10¢ below the M-W price but moves up and down with it.

[5] Sections 601, 602, and 698c(18) of the Agricultural Agreement Act of 1937, as amended (USDA 1971), contain the specific statements on the objectives of the orders as stated by Congress. Also, a 1962 report to the Secretary of Agriculture by the Federal Milk Order Study Committee (USDA 1962, pp. 12–13) outlined the Committee's views on what were the major objectives of milk orders. See also Ward.

The economic rationale on how the classified pricing and pooling regulations of milk orders serve to achieve the goals of milk orders is discussed in the following sections.

Stabilize fluid milk prices. Classified pricing provides an economic incentive for farmers in the aggregate to produce more Grade A milk than is actually needed for fluid use plus an adequate reserve. The impact of Class I differentials being consistently above cost-justified levels is to encourage Grade A dairy farmers sharing in these higher-valued sales to increase their milk production and for some Grade B dairy farmers to convert to Grade A milk production (Buxton 1978). Higher fluid milk prices also discourage fluid milk consumption. The net result is a Grade A milk reserve that either can be used as fluid when needed or diverted into manufacturing when not needed. This eliminates the probable wide fluctuations in the fluid milk price relative to the M-W price due to seasonal and other unsynchronized variations in supply of Grade A milk and fluid demand.

This approach to stabilizing fluid milk prices works only if a secondary market exists for the Grade A milk not needed to meet fluid demand.

Market security. Pooling the returns from the sale of all Grade A milk reduces the concern of farmers as to whether their specific milk is used in fluid products at the higher Class I price or in manufactured products at the lower Class III price. Farmers are paid on the basis of a market average price regardless of how their specific milk is used. Without pooling, an individual farmer or his cooperative association would be under economic pressure to sell as much of his or their own milk as possible in the higher-valued fluid market. Strong competition for the fluid market likely would develop as long as farmers could realize a higher price in that market. Some Grade A farmers probably would be dropped from the Grade A milk market during the season of highest milk production when Grade A milk supply exceeded fluid use. This would leave the farmer seeking an alternative manufacturing market outlet for the extremely perishable milk. Switching back and forth from the fluid to manufacturing market may be difficult and at times results in distressed milk prices and even uncertainty as to whether an outlet exists.

The classified pricing and pooling regulations of milk orders, then, reduce the need for "switching" outlets and provide Grade A dairy farmers with more secure markets.

Balancing market power. For a long time the dairy industry was characterized by many small dairy farmers selling milk to a relatively few large handlers. Minimum Class I prices under milk orders protect dairy farmers from the effects of possible price wars or other price-cutting activities by handlers. Such supervision of the terms of trade is more likely to promote constructive competition for a commodity as perishable as milk.

Increase farm income. Classified pricing that charges a higher price for the relatively more inelastic demand for fluid milk is a form of price discrimination. Returns to Grade A dairy farmers are increased by charging a higher price for milk used in the relatively inelastic fluid market than in the manufacturing market.

To summarize, there is a logical rationale by which classified pricing and pooling provisions of federal milk marketing orders can be used to achieve "orderly" marketing and "adequate" supplies of milk and to improve incomes of Grade A dairy farmers. Fluid milk prices have not been more unstable relative to manufacturing milk prices, and fluid beverage milk is available year-round in essentially every grocery store across the United States. Also, Grade A dairy farmers are assured of a stable outlet for their milk even when large quantities of Grade A milk are diverted into manufacturing. These aspects of milk marketing are held by many as benefits of the federal milk marketing order program.

Other benefits of milk orders include the collection and dissemination of timely and accurate market information, unbiased audits, and verification of weights and tests of farmers' milk.

Our inability to measure quantitatively some of the benefits complicates any attempt to measure public interest specifically. It requires that policymakers must consider the trade-offs and then make decisions on selected provisions of federal milk orders and on the federal milk order program itself.

Although the federal milk marketing order program has generally achieved its goals, two relevant questions remain: (*a*) Can the same benefits and goals be achieved at a lower so-

cial cost? (*b*) Are there alternative approaches to serving the needs of the fluid milk market? To probe these questions in more detail, the next part of this paper considers some basic economic implications of milk orders.

Economic Implications of Milk Orders

Well-developed economic principles of milk marketing provide a framework from which many of the economic implications of milk orders are derived. Particularly useful studies for analyzing the implications of milk orders are provided by Bressler, Harris, and Kessel.

Seven major implications are identified in the following sections. They are not mutually exclusive, nor are they all-encompassing, but they are considered separately for discussion purposes.

Excess Reserves of Grade A Milk

Grade A milk production has increased dramatically despite relatively small increases in the amount of milk used as a fluid beverage. Grade A milk not used for fluid but diverted into manufacturing uses increased from about 24.3 billion pounds in 1967 to over 42 billion pounds in 1977. This increase has come about as a result of both expanded milk production by existing Grade A farmers and conversion by other farmers from Grade B to Grade A milk production. The conversion has been especially dramatic in Minnesota and Wisconsin where a large proportion of the remaining Grade B milk is produced. In 1977, 66% of the milk produced in Wisconsin was Grade A, compared with only 44% in 1967. In Minnesota, the proportion of Grade A milk increased from 19% in 1967 to 49% in 1977. All milk in the United States will become eligible for fluid use if these trends continue despite the fact that less than half of the milk will likely be used for fluid.

Why are farmers converting from Grade B to Grade A milk production when essentially all the additional Grade A milk is diverted and used in the lower-priced manufacturing market?[6] There are many contributing factors, but one essential factor is that a farmer can get a higher price for Grade A than for Grade B milk.[7] A logical assumption is that unless a farmer receives or expects to receive a higher price for Grade A than for Grade B milk, he will not be willing to incur the added cost or inconvenience of the higher farm sanitary standards of Grade A milk production. Because a dairy farmer must produce Grade A milk to participate in a milk order pool, the blend price advantage over the manufacturing milk price can provide the economic incentive for a farmer to convert from Grade B to Grade A production. This is how classified pricing and pooling generate a reserve of Grade A milk and therefore contribute to orderly marketing. If Class I price differentials in milk orders can be set at levels to provide a necessary reserve it would be possible to set them at still higher levels, which would result in excess reserves. An important implication of the rapid and likely nearly total conversion to Grade A milk is that Class I prices have been set higher than can be justified for stabilizing fluid milk prices, providing market security, providing adequate quantities of Grade A milk for the fluid market, and otherwise achieving orderly marketing conditions. Harris recognized this by pointing out that if classified pricing were used to achieve only market stability and security, that "there would be no tendency toward expansion of supplies beyond the effective demand requirement of the market" (pp. 66–67).

Geographical Price Distortions

Setting minimum Class I differentials in order markets east of the Rocky Mountains according to how far the market is located from Eau Claire, Wisconsin, ignores supply and demand conditions for fluid milk in those markets. Why should the Class I price in any market reflect transportation costs for fluid whole milk from Eau Claire when that market has more than enough Grade A milk plus a reserve to meet its own fluid demand and no milk is actually transported? For example, in 1977 the New England milk market, where essentially all milk is Grade A, utilized only 59% of its milk as fluid while 41% was used for manufacturing. This is more reserve than is needed to meet fluid demand by most standards and is

[6] At present, there appears to be no public health concern over the consumption of manufactured dairy products made from Grade B rather than Grade A milk. Therefore, converting from Grade B to Grade A milk is not nor has it been explicitly stated as a goal of classified pricing.

[7] The economic relationship between classified pricing and excess Grade A milk is explained in Buxton 1978.

evidenced by the fact that no fluid milk is shipped from Eau Claire, Wisconsin, into New England. Yet, in 1977 the average minimum Class I price was $11.46 in New England compared to $9.74 in the Chicago regional market (USDA 1978, pp. 44 and 52). In the absence of regulation and assuming a reasonable degree of competition, competitive forces would be expected to cause the Class I price to fall in New England.

The present policy of using a single-price basing point in Eau Claire ignores possible multi-basing points in other surplus areas such as New England. The implication of geographically distorted prices is to encourage milk production in relatively inefficient production areas.

Preliminary research indicates that the distortion favors milk production in the Northeast, South, and West over the Lake States, Corn Belt, and Plains (Fallert and Buxton). However, additional research is needed on evaluating the exact magnitude of the distortion and the implications of following a policy to reduce this distortion.

Expanded Milk Production

Classified pricing and pooling creates a divergence between the price a farmer receives for his milk and the value of that milk in the marketplace. An additional amount of milk produced will be worth the blend price to the farmer but worth only the Class III price in the market because it must be diverted into manufacturing. The divergence, giving inaccurate price signals to Grade A dairy farmers, would be expected to result in the farmers producing more milk individually and in the aggregate than they would if they received the market value rather than the calculated blend price.

The average price received for fluid eligible milk in 1978 was $10.79 per hundredweight while about 40% of that milk was sold at the manufacturing milk price of $9.68 (USDA 1979, p. 28).

Depressed Manufacturing Milk Market

Increasing Class I differentials encourages milk production, as described above. It also discourages fluid milk consumption by increasing fluid milk prices. The combined impact is to increase the amount of milk that must be used to make additional manufactured products to be sold in the manufactured dairy product market. These additional manufactured dairy products tend to depress the manufacturing milk market. The actual impact on the manufacturing milk price (Class III price) depends on whether the market price is at or above the manufacturing milk support price. If the market price is the same as the support price, the government will purchase, under the price support program, the added dairy products resulting from the higher Class I differentials. If the market price is above the manufacturing support price, then the added dairy products would depress manufacturing milk prices. In both cases, classified pricing and pooling provisions under federal milk orders tend to keep the manufacturing milk market depressed.

Only Grade A Farmers Benefited

Only Grade A dairy farmers receive higher milk prices as a result of classified pricing and pooling under milk orders. Because relatively high Class I differentials under milk orders tend to depress the manufacturing milk market, Grade B farmers are worse off, or at best no better off, as a result of them. It is true, however, that many Grade B farmers, by converting to Grade A milk production, can also benefit. However, this is a forced situation because the only alternatives to converting to Grade A milk are to accept the Class III price for their milk or quit dairy farming altogether.

Because milk markets do not benefit Grade B farmers, pursuing the goal of classified pricing to increase the income of Grade A farmers raises a major equity question: Can classified pricing legitimately be used to improve farm income when all farmers do not benefit?

Inefficient Movement of Milk

Once a cooperative which is manufacturing dairy products principally in plants located relatively close to a fluid market ships enough milk to qualify for the pool, the incentive to ship additional Grade A milk to the fluid market is greatly diminished. If it does ship additional milk to the fluid market, it will not pay its producers any more for their milk. There is an actual disadvantage in shipping milk to the fluid market since the cooperatives that have manufacturing facilities would want the largest volume of milk possible to lower unit costs in their own manufacturing operations. Negotiated Class I prices above federal order min-

imums help provide the incentive for such cooperatives to "give up" the milk in their own manufacturing operations and ship it to the fluid market. This means that increased Class I differentials still may not get the milk needed for fluid use.

This situation creates a need to go further distances from the central market to obtain enough milk for fluid demand even though closer supplies exist. To the extent that this phenomenon exists, fluid handlers need to bring milk for fluid use from more distant areas than likely would be the case without regulation. Many factors influence the manner in which cooperatives serve the fluid market; only general forces and implications are pointed out here.

Restrictions on Reconstituted Milk

The present order program assumes that fluid milk demand must be met with fresh whole milk. As discussed, a reserve of Grade A milk would be needed under this assumption to balance seasonal and day-to-day variations in supply and demand and thereby stabilize prices.

However, it has been technically possible for some time to commercially recombine nonfat dry milk, milkfat, and water into a fluid beverage milk. This reconstituted product could then be blended with fresh whole milk to meet fluid demand. In effect, this would provide a storable reserve rather than a fresh fluid milk reserve. Presently, there are provisions in federal milk marketing orders that effectively raise the cost of reconstituted milk so as to make it an uneconomic alternative.[8]

A recent report has taken a preliminary look at the effects of reconstitution on regional prices, utilization, and production (Hammond, Buxton, and Thraen). Results indicate that the maximum Class I differential would be less than the actual Class I differentials that now prevail under federal and state marketing orders. Generally, the Class I differentials based on fluid transportation costs from Eau Claire, Wisconsin, could no longer hold.

Another implication of this alternative would be that Class I differentials high enough to create a necessary fluid reserve could no longer be justified on the basis of stabilizing fluid milk prices. The storable reserve could achieve the same orderly marketing objectives as previously attributed to the fresh fluid reserve.

More research is needed on the potential of other possible alternatives. For example, about 2 pounds of nonfat dry milk and 21.3 pounds of water may be blended with 100 pounds of fresh whole milk of 3.7% fat to yield 123.3 pounds of fluid milk with 3% fat. The average fat test of all fluid beverage milk is now 3% fat. Also, frozen concentrated milk, like frozen concentrated orange juice, would reduce transportation costs, increase shelf life, and could open new markets for fluid milk domestically and overseas.

A major implication of the present milk order regulations is that they distort the economic feasibility of possible innovations for serving the fluid milk market more efficiently without sacrificing orderliness or adequate supply objectives.

This raises an interesting question: What kind of fluid milk industry would evolve if the only economic use of milk was as a fluid beverage? Clearly a reverse, much of which would need to be dumped, would be costly. A great deal of innovation would be expected to avoid waste. Storing fluid milk as nonfat dry and milkfat ingredients or in other forms to be recombined probably would be an integral part of such a dairy industry.

Conclusions

The economic principles of milk marketing and current research methodology contribute a great deal to evaluating the impact of milk marketing order regulations. However, all the questions have not been answered. There is presently no methodology that can predict with a high degree of confidence what the real world would look like without the federal milk marketing order program. The competitive model may not accurately reflect the conduct of cooperatives and handlers. Would or could cooperatives step in and impose the same results as are achieved under market order regulations? Are some regulations needed to create a healthy competitive environment?

At the present time, no model or methodology exists that can predict whether disorderly and chaotic conditions definitely would appear in the absence of regulation. Could the technological changes in handling and transporting

[8] Seven states have outright prohibitions on the production and/or sale of reconstituted milk while 9 states have Grade A standards that effectively prohibit the sale or manufacture of reconstituted products (Hammond, Buxton, and Thraen, pp. 18–19).

milk and the ability to store fluid milk in ingredient form result in orderly marketing of milk without the present regulations? Even if the answer were yes, would such a change in policy be in the public interest by increasing social welfare? Which groups would benefit and which would lose? What kinds of resource adjustments would be required? These questions require additional research even though considerable work has been done. The research must be a broadly focused, no-holds-barred approach. There is a tendency for a "conventional wisdom" on why things cannot be done differently to appear in connection with long-established regulations.

The economics of milk marketing and research methodology are sufficiently well-developed to identify some of the major economic impacts of milk marketing regulations. A major conclusion is that the goal of increasing returns to Grade A dairy farmers has been explicitly or implicitly pursued beyond that needed to stabilize fluid milk prices and provide market security. Reducing Class I differentials from the present levels, therefore, would be possible without risking the market stability, security, or adequate supply objectives. The decrease would need to be made over time in small incremental amounts since present research methodology is not able to identify the exact cost-justified Class I differentials in all federal order markets with a high level of confidence.

Although the relevance of welfare theory is still a matter of debate, it represents the best methodology available for evaluating whether lowering Class I differentials would be in the public interest.[9] The results of the previously mentioned studies indicate that lower Class I differentials would increase social welfare while raising Class I differentials would do the opposite. This would be the conclusion as long as the Class I differentials were not lowered below the level needed to provide a necessary reserve and thereby to stabilize fluid milk prices.

Another significant conclusion based on the economics of milk marketing is that a geographical distortion exists in the Class I price. This distortion results from implicitly assuming only one surplus fluid milk area from which Class I prices in all other markets are aligned according to distance. This ignores supply and demand conditions in various regions of the United States. In addition, welfare theory seems adequate to conclude that reducing the distortion is in the public interest. However, the impact will be quite different among regions. The adjustments imposed on dairy farmers in the regions where price would be most affected (Southeast) would be considerable. Perhaps compensating those most affected would reduce the impact while still moving toward a more efficient system.

A real limitation in analyzing milk orders is a lack of good estimates on how dairy farmers in selected regions and consumers would respond to significant price changes. Better supply and demand estimates are needed. If obtained, they would, in combination with conventional economic theory, provide a great deal of useful analysis for policy decisions regarding milk marketing regulations.

[9] After review of welfare theory, Currie, Murphy and Schmitz concluded that it was the most useful tool available for many kinds of policy questions despite some limitations.

References

Bressler, R. G. *Pricing Raw Product in Complex Milk Markets.* USDA Ag. Econ. Res., vol. X, No. 4, Oct. 1958.

Buxton, Boyd M. *The Disappearance of the Grade B Milk Market—A Matter of Policy Choice?* USDA ESCS Agr. Econ. Rep. 416, Dec. 1978.

———. "Welfare Implications of Alternative Classified Pricing Policies for Milk." *Amer. J. Agr. Econ.* 59 (1977):525–529.

Currie, J. M., J. A. Murphy, and A. Schmitz. "The Concept of Economic Surplus and Its Use in Economic Analysis." *Econ. J.* 81 (1971):741–799.

Dobson, W. D., and Boyd M. Buxton. *Analysis of the effects of Federal Milk Orders on the Economic Performance of the U.S. Milk Markets.* Dep. Agr. Econ. Res. Bull. R2897, University of Wisconsin, Oct. 1977.

Fallert, Richard F., and Boyd M. Buxton. *Alternative Pricing Policies for Class I Milk under Federal Marketing Orders—Their Economic Impact.* USDA ESCS Agr. Econ. Rep. 491, May 1978.

Forest, H. L., "Federal Milk Marketing Orders—Their Strengths, Their Adversaries, Their Future." Speech presented at American Farm Bureau Federation Meeting, Miami, Florida, 15 January 1979.

Hallberg, M. C., D. E. Hahn, R. W. Stammer, G. J. Elterich, and C. L. Fife. *Impact of Alternative Federal Marketing Order Pricing Policies on the United States Dairy Industry.* Pennsylvania Agr. Exp. Sta. Bull. 818, May 1978.

Hammond, Jerome W., Boyd M. Buxton, and Cameron S. Thraen. *Potential Impacts of Reconstituted Milk on Regional Prices, Utilization, and Production.* University of Minnesota Agr. Exp. Sta. Bull. 529, 1979.

Harris, E. S. *Classified Pricing of Milk, Some Theoretical Aspects.* USDA Tech. Bull. 1184, 1958.

A Regulator's Perspective On Regulatory Research

Gary L. Seevers

There is no question that government regulation, viewed in the aggregate, has become a major influence on the performance of the economy in general and the food system in particular. As a result, it is essential that economists devote more of their own resources to developing a better understanding of the costs as well as the benefits of regulation. This will enable the political system to formulate regulatory policy more responsibly and it will help regulatory agencies implement that policy most efficiently. I am pleased to be invited to participate in this conference as I firmly believe that the application of economic analysis to this relatively new area of public policy has the potential for high social returns compared with other areas of work.

When I came to Washington from Oregon State University nine years ago, I had little interest in regulation and no teaching or research experience. I soon learned that regulation was a priority area of work at the Council of Economic Advisers. The Council was active in advocating less regulation of surface freight transportation, commercial airlines and natural gas production. The Council was also conducting analysis of the newly-emerging environmental regulations.

I first was exposed to the Council's regulatory analysis while I was on the staff. After I became a member, a major part of my responsibility was to coordinate the Council's regulatory analysis and represent the Council inside and outside government. Unfortunately, the amount of work which was needed greatly exceeded the capacity of the Council's small staff of two professionals in this area. This was especially true since new regulatory programs and requirements were proliferating rapidly in the early 1970s.

During the past four years I have been deeply involved in establishing a new regulatory agency which oversees commodity futures trading. My remarks today, therefore, will be from my experience as a regulator—from the inside, so to speak. The Commodity Futures Trading Commission (CFTC) was created by Congress in 1974 when commodity markets were exceptionally turbulent. In addition, establishing new federal regulatory programs was fashionable during this period. Even though Congress is more skeptical about starting new regulatory programs today, I believe they would have to establish the CFTC now if they had not already done so. I know Congress considers effective regulation of futures trading to be desirable and essential for the protection of the hedging and pricing functions of futures markets as well as for the protection of those who use the markets.

Let me make four general observations based upon my experience as a CFTC Commissioner. I hope my perspective will help you determine how to get a handle on regulatory research, which is not an easy task.

A Limited Role for Economists

The role of economists in most regulatory agencies has been small in the past. If I may take the liberty of comparing their role with that of lawyers, for instance, far more commissioners and agency heads are lawyers than all other professionals combined. Perhaps even more significant, lawyers dominate the makeup of most agency staffs and they have been more effective within the agencies than economists. Regulation has been primarily legal and adversarial and, of course, lawyers are trained to be advocates. What economists have to contribute is by nature more conceptual and conjectural, rather than concrete and decisive.

Legal work is also very labor-intensive. One fairly minor case can tie up several lawyers for months. The first chairman of the CFTC and I reached an understanding about the role of lawyers and economists. We used to have friendly but real debates about how many positions should be allocated to economic pro-

---

Gary L. Seevers is a former commissioner, Commodity Futures Trading Commission, Washington, D.C.

grams, and how many should be allocated to legal and enforcement programs. He would say that committing resources to research is like investing in an "ethereal cloud"—it might pay off way down the road. And I would say that hiring more lawyers to work on cases is a "bottomless pit" which could consume everyone in the agency.

Enforcement cases are easy to get your teeth into. There is a strong tendency for such "visible and specific" activities involving the righting of individual wrongs to crowd out activities like market-wide surveillance, economic studies and research that have a broad, long-term payoff. Regulation is a long, deliberative process and most regulators are reluctant to wait for research results. Economists can serve a useful function in regulatory agencies but it will not happen without a determined effort by the economics profession.

The CFTC has a higher proportion of economists among its professional staff than any other regulatory agency. Futures markets are economic institutions which require close monitoring and, as a result, we simply must have a large number of market analysts and economists. Nevertheless, it is a constant challenge to keep a reasonable balance of lawyers, economists and other professionals. One important factor is that new attorneys can be employed quite easily (as Schedule A employees) whereas employing new staff in other professional positions is always time-consuming and sometimes impractical due to civil service procedures.

Growing Demand for Economic Analysis

Fortunately, the role of economists in regulatory agencies is improving. There is more appreciation of the need to include economic analysis in the design of specific rules and regulations, and in the development of overall policy. Concern about the economic costs of regulation is increasingly evident in the Congress and has been recognized for some time in the executive branch, especially among those responsible for dealing with inflation. The consequence is pressure on regulatory agencies to include more economic analysis in their work.

Agencies have a choice between an economic approach to regulation and a purely legalistic approach. Public opinion and political concern definitely are creating the opportunity for agencies to pursue the economic approach. As this occurs there will be more opportunities for economists to be decision-makers, policy advisers and analysts, and to conduct studies and research.

The economic approach to regulation involves an attitude that leads to asking the right questions. Certain questions will be asked if an agency is following the economic approach. These will vary depending on the type of agency, but some useful questions are:

(*a*) Is a regulation really necessary, or will competition provide satisfactory performance?

(*b*) If a regulation is justified, would it be better done by industry self-regulation?

(*c*) How much burden will the regulation impose on those being regulated?

(*d*) Is the regulation enforceable, and at what cost?

(*e*) Does it provide economic incentives to achieve the desired objective?

(*f*) Does it provide useful information to the buyer or beneficiary of the regulation?

(*g*) Will it actually contribute to the objective being sought, or does it only give the appearance of contributing?

(*h*) How will it affect industry structure and competitive incentives among firms?

Obstacles to the Economic Approach

My third observation is that there are serious obstacles to stressing economic analysis in the regulatory process.

An administrator of a regulatory agency needs plenty of information and research when he follows the economic approach. It is difficult to have the pertinent information when it is needed, and administrators are often faced with the pressure to make decisions based on insufficient information. A new agency usually has statutory deadlines, insufficient resources and inexperienced personnel. An established agency usually has an enormous backlog of decisions to make. The CFTC Commissioners were constantly asked to adopt regulations without factual back-up in our early days. On many occasions I recall saying, "let's get the facts before we start regulating."

There are several reasons why there is so much regulation without first getting the facts.

One reason is a procedural pitfall in the regulatory process. Regulations are first proposed

in the Federal Register. It is easy to reason that a draft regulation prepared by your staff is only a proposal and agree to go ahead and solicit public comment on it even though the proposal may not have as much supporting documentation as you would like, and is only one of several alternatives. Unfortunately, this process may lock the regulator into that particular approach. This is why exploring alternative approaches is so essential as a first step. The CFTC now makes it a practice to have a general policy discussion where alternatives are examined before we consider a concrete staff proposal.

Another problem is that the Advisory Committee Act, along with a general concern about industry representatives having too much say in formulating regulations, precludes much informal solicitation of views prior to publication in the Federal Register. As a result, when regulations are first published, they often are not practical or thoroughly thought out. Once in the Federal Register, however, they enter a formal adversarial process which has numerous deficiencies.

A third problem is that regulatory agencies simply try to do too much. They fail to set priorities. An agency's budget is always tight and, in the short-run (six to twelve months) it is fixed. For most agencies the chances of "real" increases in their budgets are not good even over a longer period. Faced with fixed resources, it is important to set priorities and avoid taking on too many activities. Otherwise, each activity will be constrained to "stage one" of its production function.

I think there are significant diseconomies of size which are not well understood or appreciated in many government activities. To say it another way, agencies try to do too much and they end up not doing the important and possible things well. This problem certainly existed at the CFTC in our early years. Setting priorities is not only essential to good allocation of resources, it is also important if agencies are to follow the economic approach. The reason is that the economic approach has higher up-front costs; it requires more information, more research and more critical examination when regulations are being adopted.

If new agencies undertake too much rule making, they spread resources too thin and will be driven toward the legalistic approach. Over time this does not really save resources, however, because the higher up-front costs for the economic approach are more than offset by higher costs of administering and enforcing regulations.

Useful Regulatory Research

While the demand for regulatory research is there, the supply response is a real challenge. For one thing, it is difficult to undertake meaningful research when you are based at a university or research institution away from the agency. The CFTC has had little success with contract research. Timeliness and relevance are both problems as well as supervision to make sure the researcher follows the project's objectives.

The CFTC has had better success with in-house studies of particular regulatory problems. We also have a good record of applying economic analysis to many aspects of our regulations. But this happens when specific regulatory needs arise and the staff is directed to work on a problem. When in-house research is undertaken outside the context of specific needs of the Commission, it has not been very productive either.

This presents a dilemma for the academic researcher and for us. A definable regulatory problem seems to be needed to focus research, but by that time it is too late to solicit outside research.

We are now in the process of reviewing our entire research strategy. My conclusion is that the CFTC should devote most of its discretionary research funds over the next four years to descriptive research about the structure of the futures industry and about basic information such as who uses futures markets. One of our most valuable projects was a survey study of what types of firms and individuals are making use of the new financial futures markets in interest rates and foreign currencies. Little is known about many basic aspects of the markets and the futures industry, and the CFTC is in an advantageous position to generate and assemble such data and information.

The supply side of regulatory analysis is something that has to be worked on by economists if they expect to be heard, and to make a contribution. How does someone who is interested in regulatory research proceed?

I think it is important to make a strong commitment to an area for at least five years—probably to a particular agency or program. Be willing to familiarize yourself with the industry that is being regulated. Monitor

what the agency is doing, read articles on the legislative background and legal side of the agency. Get to know its staff as well as its programs. Expect to stray beyond conventional economic problems because regulatory analysis seldom, if ever, comes in clear and easy forms.

The potential for social payoff is large, however, judging by the successful research studies done in recent years that have contributed directly to regulatory reform efforts. Today, more than ever before, there is a market for economic analysis in the formulation and implementation of regulatory policy.

Cumulative Impacts of Regulation

Barry P. Bosworth

This paper discusses some of the cumulative impacts and aggregate effects of regulation, particularly as they relate to inflation. To provide some framework for the discussion, I want to give a perspective on the issue of inflation and the way regulation is part of that problem.

Without getting into all the complicated causes of inflation, I think there is one approach which provides something of a framework for looking at the issue. Inflation problems can be separated into three rather broad areas. It is necessary to keep them separate to keep them in perspective.

Momentum Inflation

The first is momentum inflation. Momentum inflation has very little to do with regulation. It simply has developed in this economy after over a decade of continuing inflation and the expectation that inflation is going to continue. Therefore, we probably have in the range of 7 to 8% a year of continuing inflation that is not of the classical economic type which says that inflation is due to excess demand—too much money chasing too few goods. It is more like a merry-go-round—a defensive posture.

I think it is interesting, for example, to look at the Teamster negotiations that were completed this year. In spite of all the newspaper articles that were written about those negotiations and whether or not they complied with the guidelines, there was one issue that never came up. That was whether anybody thought that there was a surplus of truckers or a shortage of truckers in this country. Those questions, it was thought, had absolutely nothing to do with the issue of what was the appropriate increase in wages. Instead, we have this momentum inflation. It is a situation where people believe that their own wage increases are justified because of past price increases. Each group is trying to match the wage increases of coal miners and Teamsters and others they read about in newspapers. Then, they want to add a little bit on top of that because they expect the whole process to continue and they have to keep up until the next time they get a wage increase.

On the business side, I think you see much of the same thing. Businessmen, for the most part, are raising prices to levels they think are justified in order to recover the cost increases for past wage increases and the increased cost of materials. And, perhaps, they are adding a little bit on because they expect the whole process to continue. The momentum has built up over a long period of time and now runs at fairly high and steady levels.

Most Americans have come to realize that they are not really benefiting from that inflationary momentum. They are beginning to realize that no one is making any appreciable gains. They are learning that their wage increases are simply being matched by others and followed by price increases. Most Americans now feel that they would like to get off that merry-go-round, if possible. But they hesitate to do so because they have absolutely no faith that anybody else will do the same thing. As long as everybody feels that no one else will show restraint, no one can afford to show restraint, and so the whole process simply continues. Momentum inflation has little to do with excess demand pressures in the economy or a shortage of labor or a shortage of capacity in most of the basic materials industries. It has everything to do with psychology.

Shocks to the Economy

The second part of that process, which intensifies inflation and makes it worse, is the fact that shocks are occurring constantly in the economic system.

For instance, bad weather drives up prices in the agricultural sector suddenly. As a result, beef producers liquidate the herd. A few years later beef prices increase and then people say, "I know there is a shortage of it. I know that the country has to cut back on beef consumption because we cannot raise more cattle in the short run but, I do not want to bear the bur-

---

Barry P. Bosworth is former Director, Council on Wage and Price Stability, Washington, D.C.

den." Pressure intensifies for wage increases that keep up with the beef price increase or gasoline price increase or what have you.

Another effect of those shocks is a growing awareness that the United States is no longer in a position to dictate world economic conditions. The disruptions that occur in other countries, including the economic policies they follow, upset the pattern of wage and price changes in this country and, therefore, touch off further rounds of wage and price increases domestically. One of the best examples was the Iranian oil crisis.

Our own people and policies aggravate the situation. We resist changing our institutions to buffer ourselves against the impacts of these external shocks and then, to make matters worse, we do not accept the consequences. We are used to thinking that if food prices go up, somebody is responsible, and the government will do something about it. Many Americans believe it is not necessary for us to learn to live with changed relative prices.

Five years after the big increase in oil prices, Japan and the European countries have accepted the fact of life that energy is going to be more expensive. They understand the need to adjust to that situation and go on. In the United States, on the other hand, five years later, we are still fighting over who is going to pay for those higher energy prices. Everybody feels that somewhere in the process it will be possible once again to find cheap energy.

Drop in Productivity Growth

The third area—which does bear directly on regulation—is related to the fact that the federal government and, to a lesser extent, state and local governments, constantly are taking actions that tend to exacerbate the price pressures. They either initiate a price increase in one sector or a wage increase in another or they take some other regulatory action that has the same result.

These actions divide themselves into two areas: One we would refer to as regulation, or changes in the rules of the game under which the system operates. The second, closely related because it also involves changes in the rules, is special interest legislation.

Both relate to the third area and the third problem that we face in the current inflation, the major decline in the rate of growth of productivity in this country. This country had a rate of productivity growth from the 1950s through most of the 1960s of about 3% a year. A period of price stability in the early 1960s up to about 1965 was accompanied by rates of improvement in productivity of 4 to 5% a year. In the last decade, however, productivity growth in this country has been less than 2% a year.

Many economists and individuals argued that the decline in productivity growth was simply cyclical and related to the fact that in that decade we had two severe recessions. They said that if we just had an expansion of the economy, productivity growth would recover and the rate of inflation would moderate. However, the last two years have been years of strong economic growth, major reductions in unemployment and what, if you only looked at the real side of the ledger, most people would say was an abnormally well-balanced strong economic expansion. Yet, the rate of growth of productivity has been less than 1%. It has become clear to everyone that this country is facing a somewhat permanent and major reduction in the rate of growth of productivity.

The question is how do we account for it? Most businessmen blame a capital shortage. But, it is important to remember that the rate of productivity growth in this country declined not just in recent years but from 1967 to 1973 as well. That was a period when the rate of growth of capital formation was stronger than it has been at any time in the post-war period. Yet, productivity growth declined. The period of decline in productivity coincident with the decline in capital formation has been only since 1973. Economists' efforts to identify the contribution of capital formation to productivity growth are always rather nebulous and difficult to pin down with precision. It seems clear that the slowdown in the rate of growth of capital formation only can account for a small proportion of the total decline in productivity.

Some people point to the fact that there has been a shift in the age and sex mix of the labor force. This period, they say, has been one of very rapid labor force growth and, therefore, the United States has an abnormally inexperienced labor force. Because so many women and young teenagers have come into the work force with relatively limited previous work experience, some claim the average efficiency level of that labor force is less than it was in

the past—and that has contributed to the slowdown in productivity.

If that were a reasonable explanation for the slowdown in productivity, the country could look forward in the 1980s to a very rapid growth of productivity because those young and inexperienced workers will be middle-aged and very experienced by then and the rate of growth of the labor force will slow down during that period. Empirical attempts to identify that contribution to productivity slowdown, however, have indicated that, particularly in the last five years, its contribution is extremely limited and cannot explain the major slowdown in productivity.

Capital formation could account for something between three-tenths and four-tenths and the shift in the labor force may account for something like one-third of the slowdown.

People also have pointed to such factors as the shift in the industrial mix of output. But all the empirical studies attempting to identify that factor have shown that the industrial shift, the so-called move to services away from goods, has not in fact occurred. Secondly, it is not true that the service sector of the economy has a lower level of productivity than the rest of the economy. Therefore, unless you want to count the move out of agriculture being offset by the growth in government, there has been no impact or shift in the industrial mix of output. In the private, nonfarm sector of the economy, there has been a major slowdown in productivity and, within that sector, you can find no contribution being made by the shift in industrial mix of employment.

That still leaves us essentially with the problem of trying to explain what has happened to productivity growth. People have pointed to research and development, but again empirical estimates to determine the extent of its impact have been very limited.

Impact of Regulation

One area that has had a significant impact on the rate of growth of productivity—has been the growing role of federal regulation and special interest legislation. The impacts of regulation typically do not show up as a higher profit margin and they do not show up as a higher wage rate. They show up instead as a decline in the measure of the rate of growth of productivity formation in the country. Attempts to estimate the impacts of regulation in individual industries and to aggregate those impacts suggest that, while it would be a gross exaggeration to say that regulation is the major cause of the slowdown in productivity growth, it has been an important contributor. The electrical utility industry, for example, used to show a very rapid growth in productivity and, for the last five years, has shown almost none. The construction industry has experienced major declines in the rate of growth of productivity. The mining industry used to experience between 3 and 5% growth in productivity a year but, since 1971, productivity has actually declined 40%. In surface mining, productivity is down about 20%.

Putting those facts together shows that there are important, significant aggregate effects on productivity growth from rapid growth in regulation. At the same time, it is very important to keep in mind that those regulations brought with them both benefits and costs and the two have to be balanced off against each other. In many ways, you are dealing with regulation in areas where the benefits are not precisely economic and, therefore, cannot be measured simply by looking at productivity. For instance, you have to make adjustments for the environment. But even if that is true, I think that, while there might be general agreement that the goals of regulation have been desirable and meaningful, it is extremely important for people to keep in mind that regulations are not free. Too much of the present attitude indicates that people believe that they are free. They want to improve the environment, to improve worker health and safety, but, the costs of regulation to achieve these goals, unlike most government activities, do not show up in the federal budget. Instead, they show up as increased costs and, therefore, higher prices in the private sector. At that point, everybody calls it inflation and they argue for a wage increase to compensate.

One of the problems has been that regulation has no automatic mechanism by which people agree to pay the cost. There is no direct way to demonstrate that they must be willing to reduce the demands they place on the economy to compensate for improvement in the environment or in health and safety. One of the problems is that there is not a general public acceptance of the effects of regulation nor a willingness to pay for them, except for a willingness to have everyone else pay for them.

There are a couple of other difficulties with

regulation. First of all, social regulation as opposed to economic regulation is relatively new. Like any other new industry, particularly when that industry is run by government, it is done poorly. In the regulatory area, one of the major gains that we can make is to try to distinguish between the goals and the means by which we try to achieve those goals. Too often much of the debate is about the goals. Business will say that it is not worth following because the needed regulations will increase costs. But they also bring benefits and those have to be recognized. When agencies like the Council on Wage and Price Stability (CWPS) and the Council of Economic Advisers (CEA) try to take an interest in some of these regulations and indicate that there may be a cheaper means of achieving the same goal, then usually the newspapers headline that the CEA or CWPS is at it again; that these agencies do not care about the value of a human life or that they want to destroy the environment. Yet, if you look at most of the regulatory proceedings, it is not the goals that are questioned. In most of the regulatory proceedings, you will find that the issues relate to the means by which the goals are to be achieved.

Approaches to Regulation

One of the largest areas of waste has been the insistence of regulatory agencies on specifying the design standards, the method by which compliance with the law is achieved. Almost never is the focus on performance standards. Performance standards set targets and let the industry determine how to achieve them. As a result of setting design standards we have inhibited incentives for private business or other groups to find ways to improve the efficiency of efforts to clean up the environment and to achieve other regulatory goals. In the current regulatory framework, if you are a businessman and know of a way to reduce pollution from your plant, you should keep it a secret because the moment you mention it, the regulatory agency will find out about it and order you and everybody else in industry to do it. It can only end up costing the firm money with no incentive to find a cheaper way to do it.

CEA and CWPS are trying to get the government to focus on the target, the objective they want to achieve and then leave it up to the industry to determine the cheapest way to accomplish the objective. The moment that pollution costs business something, business will have the same incentive it does with other cost factors. The effort will be to minimize those costs and find a more efficient way of reducing pollution.

A Structure for Regulation

The broader problem that this Administration has tried to address relates to the rule-making procedures. The Administration is concerned about the whole institutional structure by which we undertake regulation. Most of what government is doing today lies outside the budget. If regulatory agencies were spending tax money, everybody would understand that tax funds are limited, that there are many uses for them and that we have to make choices about how we spend money in order to maximize the benefits. We would have to equalize incrementally society's value of money spent on national defense versus money spent for health and welfare. We would have to debate those issues and decide which are legitimate issues for the public to participate in.

We have a budgetary policy by which we recognize that the Department of Health, Education and Welfare (HEW) always will want a bigger budget and the Defense Department always will want a bigger budget because what they care about is pursuing their own department's objectives. It is the task of the Office of Management and Budget (OMB) to balance those choices, and to present them to the President in a logical framework so that he can make some choices about priorities. If there is a limited amount of money available, the President wants to make sure we spend it so that at the margin in every area we are getting the same incremental benefits.

Many of the budgetary concepts that are applied to the use of tax dollars can be applied in the area of regulation. Regulation uses society's resources, but by a method different from collecting tax revenues and making the cost explicit. Regulation orders people in the private sector to do something and the cost shows up in the private sector. Society still ends up paying for the regulation. But, in the regulatory area, there is absolutely no budgetary framework. The Environmental Protection Agency (EPA), for example, has 20,000 employees interested in minimizing the damage done to the environment because that is the task EPA has been given. The Occupational

Safety and Health Administration (OSHA) wants to improve worker health and safety. Everyone in these regulatory agencies is dedicated to pursuing their agency's objectives, but there is no counterbalance. There is no attempt to make sure that the amount of money that goes to EPA and the benefits that are derived from it at the margin equal the benefits we would receive if we spent another dollar for OSHA or another dollar for HEW welfare programs.

But this is not a new problem. If you read the public newspapers from the time the White House Bureau of the Budget was formed you will find that the same thing went on. The argument then was that the President had no right to tell the Defense Department or any other Department what its budget proposals should be. The first effort was to see whether or not the President could get the agencies to send over their budget proposals at the same time. The process started out with the departments simply sending their budgets to the White House where they were bundled together and sent to the Congress. Gradually, a concept of Presidential review evolved and there came to be an Office of Management and Budget and a budgetary process that tried to ensure that the demands of the various agencies were constrained within limits.

Congress has realized that it has the same need to balance the demands to achieve various social goals and recently it has set up a congressional budgetary process. I think most people who look at the current federal budgetary process believe it has led to far more rational policy decisions with respect to where we ought to spend the tax money.

The only problem with all the reforms is that, while the reforms were taking place, most of the actions of the federal government shifted outside the budget. Now the budget process is largely irrelevant to the economic effects and, to a major extent, social effects of government because the federal government is involved extensively not only in regulation, but also in the whole area of off-budget financing and all the other ways by which government achieves various national goals without having the costs show directly in the budget. Therefore, one of the problems we face is trying to develop some sort of budgetary framework within which we can evaluate the conflicting interests of different regulatory agencies. In order to do that, we need some way to measure the benefits and costs of regulations. That is the challenge to economic analysis. This does not mean that regulation has to be reduced to a Corps of Engineers cost-benefit memo. One of the nice things about most human beings is that they are able to think in several dimensions. It is enough to be able to list the costs in dollar terms where the costs are in dollars and in other terms where the costs are in other terms. And, similarly with the benefits, we do not have to value a human life and put a dollar amount on it. Instead we can talk about the number of human lives that this policy would save.

In the budgetary process we make exactly the same decisions we are currently being asked to make in the regulatory process. In order to have a rational budget, first of all, we have to arrive at a way of trying to list the costs and benefits and evaluate them. I think that is the direction we should take.

Currently, the regulatory agencies do not want to demonstrate what the benefits of proposed regulations are because once the benefits are quantified they provide a basis for applying the budgetary framework. It seems to me far better to go the way we have in the general budget. Give the regulatory agencies a budget—a total amount of economic impact that they are able to exert on the economy with the cost of the regulations. At that point, they will try to measure the benefits of their regulations and account for them because they will want a bigger budget. Agencies then will be very interested in finding cheaper ways to regulate. If costs can be reduced, that will leave more regulatory funds for use in other areas.

I know somebody will come back and say that you cannot measure these things with precision. If you go back ten years ago and look up the budget projections for the costs of the food stamp program you will find out that those costs were not measured with precision either. We make lots of mistakes in projecting the costs of programs. The real question that should be relevant is whether or not we can give an order of magnitude within which to evaluate a regulation. I would suggest today that, for most regulations, improvements in analysis have got us to the point where you can give an order of magnitude measure of the effects. In particular, although you do not know precisely the value of a regulation, you do know the value of a change in the regulation with much more precision. You can tell whether or not Approach A would be more

effective than Approach B, even though you are not too sure of the exact cost of either one. You can figure out the differences between the two. Many of the elements that are required for the purpose of budgetary policy are there. All that is important is that the regulatory agencies be given a resource allotment for planning.

I think the current regulatory framework is headed in that direction. There is an attempt now to try to get every regulatory agency to write down the benefits of a proposed regulation, the cost of that regulation and, most important, the implications of some alternative approaches for achieving the same goals. This information must be prepared and put in a public document at the time the regulation is first proposed. Then that information is available for the public to comment on in an open proceeding where other government agencies also can comment.

The original agency is supposed to improve the analysis based on the comments received, and then use it as a basis for making the regulatory decision. That begins to look very much like a budgetary process except that the agencies are not held to any sort of total budget at the present time. Experience with doing economic impact analyses of regulation has shown that the analysis can come up with orders of magnitude effects for most regulations and that has been a useful process for trying to evaluate the implications of alternatives.

Implementing a New Regulatory Framework

Adoption of this process obviously is not the total solution to inflation, but it would make a contribution toward reaching that goal: first, because it is important that we find a way to stimulate the rate of growth of productivity in terms of a long-run improvement in living standards, and secondly, because the waste inherent in some regulations is a waste of society's resources. We probably could achieve a cleaner environment than we now have if we did it more efficiently. And we could save more lives than we do now. The current estimates suggest that regulation of a social type today is probably reducing productivity somewhere between five-tenths to three-quarters of a percentage point a year. An improved framework within which those social regulations are developed probably could cut that cost in half.

The Council on Wage and Price Stability, about a year ago, tried to provide a scorecard for evaluating special interest regulatory measures, such as those participated in by the U.S. Department of Agriculture (USDA) when it fixes a minimum price or restricts trade or other such measures. CWPS found that such measures are adding somewhere between one-half and a full percentage point to the current rate of inflation. In other words just these two areas of regulation, both of the social type, and both regulations designed to protect one individual group or another add somewhere between one and one-and-a-half percentage points to the overall inflation rate. An improved framework for doing that regulation would reduce the inflation rate directly. In addition, because of the multiplier effects of regulation—price increases generate further demands for wage increases—the aggregate reduction of the overall inflation rate would probably be roughly in a magnitude of about twice that.

The basic problem we always have with changing the framework is that every time you raise a specific situation, somebody is going to stand up and say that that particular item has a miniscule effect on the Consumer Price Index (CPI). I think CWPS probably has lost patience because of the number of times USDA has said some proposal would not increase the CPI by more than 0.001%. There is almost nothing that government can do in a $2.5 trillion economy that will raise the CPI by more than 0.001%. What we forget is that government is doing hundreds of those things in any given year and, when you add them up, they have a very considerable impact on the current inflation.

Some people say that we should leave this kind of concern up to the Congress and that, once a law is passed, Congress has spoken. Anyone looking at the history of these arguments will find 90% of the congressmen did not have the foggiest idea of what they were voting for. The issues that have come up in these areas are so complicated that most congressmen simply cannot understand all the issues and, therefore, the decisionmakers are not able to evaluate the issues technically.

A second problem that has come up is that the whole political process in this country has changed so much. A politician is tempted always to vote for the special interest group. I will use the sugar legislation as an example because it has involved a lot of regulatory

agencies including USDA. There are 15,000 sugar producers in this country. There are 220 million sugar consumers. You would think the outcome of a bill to more than double the current price of sugar would be obvious. We could get sugar for about 7¢ on world markets, the President offered 15¢ to domestic producers, they are asking for around 19 or 20¢. Why is it that those bills get as far as they do? Because there are 15,000 sugar producers who do not care about any other issue short of war. If their congressman votes for that sugar bill they will vote for him. If he votes against it, they will vote against him. Those 220 million sugar consumers will never know what hit them. Nobody is going to change his vote for his congressman depending on how he voted on the sugar legislation. They will wait for the special interest legislation that comes down the pike that affects them because sooner or later everyone belongs to a special interest group—whether it be sugar producers, steel industry, environmentalists or whatever. These are people who have a single interest in life and, therefore, will vote for or against a congressman depending upon whether or not he votes for their issue.

Congressmen have learned, it seems to me, that there is a good chance of getting elected today by forming a coalition of special interest groups. And, therefore, they vote for every piece of special interest legislation or regulation that comes down the pike. That creates a very difficult problem for stopping inflation. In most of these decisions, the special interest point of view will raise the costs and prices, and the general interest point of view will lower the costs and prices. But there is no way the general interest gets reflected because these are all small actions that, in isolation, will have almost no impact on the overall rate of inflation.

Regulation Research Issues
(Dale C. Dahl, University of Minnesota, Chairperson)

Food Industry Structure and Performance

Willard F. Mueller

The reason for concern with the structure of the food system is the belief—based on theory and experience—that the competitive structure of an industry impacts significantly on its performance. This is not to say we are concerned with structure alone. On the contrary, the ultimate purpose for examining industrial organization is concern with industry performance. In a capitalistic economy operated within a system of democratic institutions, citizens have a right to establish the rules governing private enterprise to insure that it serves the public interest. It is therefore inevitable and appropriate that public policies evolve to control those with private economic power.

Types of Regulation

The American system has developed two general forms of regulation of private power: (*a*) direct regulation of performance and (*b*) indirect regulation of performance by placing restraints on certain types of conduct and structure.

When substantial private economic power is held by business, the basic threshold question is not whether to regulate, but which method of regulation to use. Historically we have used both the direct and indirect approaches to regulation. It is important to understand pros and cons of each approach.

Direct Regulation

Direct regulation has the virtue of dealing directly with performance, a task easier said than done. Consider what is required for effective direct regulation. First, the regulator must know what kind of performance is desired and possible. Each of these require enormous amounts of knowledge. Even regulation of the railroads—the first explicit effort in direct regulation via the regulatory commission (Interstate Commerce Commission—ICC) approach—has proven beyond the ability of regulators. The ICC which traditionally was concerned mainly with rate setting, and so on, required a massive amount of paperwork and a bureacracy larger than those engaged in antitrust matters—the Justice Department and the Federal Trade Commission—and, by virtually unanimous agreement, it has done an inadequate job.

More recent examples are the various laws dealing with safety, pollution and even wages and prices.

The Indirect Regulatory Approach

This approach is best epitomized by the various antitrust laws. The basic premise of these laws is that business performance is determined in large part by the competitive structure of markets and the conduct of business firms. The approach rests in the heroic assumption that a causal relationship exists between structure, conduct and performance, and that we know what it is.

Problems of Two Approaches

Each approach has its virtues and vices. Because the direct regulatory approach requires detailed knowledge to determine some desired performance and how to achieve it, the approach necessarily requires enormous bureaucratic resources. Even under the best of circumstances—which seldom are found in America—the approach is cumbersome, bureaucratic, and places strains on our political processes.

The indirect approach has the great virtue of requiring relatively few resources, since it need not get involved in the difficult problem of specifying performance and determining how best to achieve it. But this virtue of

---

Willard F. Mueller is William F. Vilas Research Professor in the Departments of Agricultural Economics, Economics, and the Law School, University of Wisconsin—Madison.

simplicity is also its greatest weakness, making it vulnerable to criticism that may paralyze the process. Because we do not know precisely how market structure and conduct impact on performance, nearly every action taken can be criticized. Contrary to the criticism of this approach, this lack of knowledge has not lead to excessive antitrust action; on the contrary, imperfect knowledge is used as an excuse for bureaucratic timidity and inaction.

I have emphasized the difference between these two approaches because they are fundamentally different though there is need for research in each area. In the past decade, the trend has been toward more direct regulation of business. This partly reflects a growing feeling that (*a*) indirect regulation has failed to maintain competition and/or that modern technological imperatives have made the antitrust approach obsolete and (*b*) the most recently perceived problems requiring regulation, e.g., protection of safety and health, can only be achieved by specification of performance. The latter occurs when the performance to be regulated is not causally related to the state of competition in any event.

Research Needs

The ultimate purpose of research into the structure and performance of the food system is to provide reliable knowledge for public policy. Of course, there is a growing body of "Chicago School" economists who believe that the world of Adam Smith has been reborn, making unnecessary any form of indirect regulation, and that public efforts to control performance directly are likely to be so wretched as to justify a virtual hands-off approach here as well. Although these views are generating much public debate, they still represent a minority view.

Research in Direct Regulation

The growing technological and economic complexity of our environment makes inevitable the growth of direct regulation. Examples of research that needs to be done relating to the food system (not in order of priority) include the following: (*a*) Cost-benefit analyses of alternative regulatory schemes relating to virtually all programs regulating performance of the food system; (*b*) Impact of alternative price and wage control systems on farmers, food manufacturers, distributors and consumers; and (*c*) Deceptive advertising and an entire array of issues relating to the advertising of food products.

Agricultural economists also can make contributions into areas primarily in the domain of applied sciences. Multidisciplinary evaluation teams such as those of the National Academy of Sciences frequently should include economists.

Research in Indirect Regulation

Research in indirect regulation requires continuing review of factors influencing the structure and conduct of industry and a better understanding of how structure and conduct impact on performance. New work needs to be done to broaden our concept of performance, as well as to examine the playback impact of conduct on structure. More attention should be given to the distributive effects of market power rather than to the economist's traditional preoccupation with efficiency. Examples of issues requiring current examination include the following: (*a*) Significance of conglomerate mergers on structure, conduct and performance; (*b*) Evaluation of the significance of existing anti-trust treatment of agricultural cooperatives; (*c*) Examination of alternative strategies of indirect regulation, e.g., the relative efficiency of case law, rule making, guidelines and new legislation requiring presumptive illegality of certain conduct; (*d*) Evaluation of past enforcement efforts to determine their effectiveness. Finally, the ultimate thrust of much legal-economic research should be aimed at determining what the law should be, not merely what it is.

Panel Discussion

During the panel discussion following this paper, a number of other issues relating to structure and performance were raised. They included the following:

(*a*) What should be done about high profits in food manufacturing?

(*b*) What is responsible for high levels of concentration in food manufacturing and why is it increasing?

(*c*) Should limits be placed on the market

share of firms to prevent the emergence of shared monopolies?

(*d*) If policy makers want to deal with the problem of growing concentration do they have the necessary legal authority? Do they have the necessary information?

(*e*) Do consumers want the kind of product differentiation which may result in market power?

(*f*) What "norm" should be used in discussing the food system?

(*g*) Do consumers benefit from food manufacturing monopolies in ways that balance some of the costs?

Food Protection: A Research Agenda

William T. Boehm

Regulatory issues have become relatively more important as agricultural policy concerns. The still-evolving role of nontraditional food and agricultural clientele is at least a contributing factor. Increasingly, concerns about the quality of life, rather than just the quantity of goods and services produced, affect the emergence of food issues and influence the ultimate decisions. Often it is felt that regulation, obtained through the political process, is the most direct route to conflict resolution.

On the other hand, there is increasing public concern regarding the direct regulation of behavior by government. Most everyone agrees that there are "too many regulations." There is little agreement, however, on which regulations should be abolished. Deregulation is sought by those who do not have a personal interest in the industry to be deregulated or the social concern that prompted the original regulation.

The conflict embodied in the present policy settling has resulted in increased public scrutiny of regulatory actions whose purpose is to achieve private or social goals. Regulatory bodies, including those dealing with food and agriculture, are now required by presidential order to make decisions only after a thorough analysis of all the evidence, including comments from the public.

Without question, such rules have influenced the economic research and policy analysis agenda. Agency administrators throughout the federal government are now allocating resources to policy analysis staffs. The challenge they face, however, is to integrate fully the insight of the economic analyst into the decision-making process.

This paper relies heavily on the recent experiences of the Economics, Statistics and Cooperatives Service (ESCS) of the U.S. Department of Agriculture (USDA) in the area of regulation research. The focus of the paper is on food protection issues, but the experiences in that area provide a framework for additional research on other domestic food and agricultural issues. Clearly, the ESCS program of regulation research is still evolving. So far, we have been responding to the research needs of the department's decision makers, but the longer-term research program needed to support this effort is not yet well thought out. Nor is it integrated with work being done on land grant and other university campuses. The hope, of course, is that meetings like this one will help to sharpen the focus of the ESCS research program and to encourage the initiation of such research at other locations.

In the time available, I will review briefly the policy setting, discuss the legal framework providing the broad guidelines for research in this area, and present a research agenda drawing from some recent work done in USDA.

The Policy Setting

Economic research is typically not conducted in a vacuum. Most often, the studies are addressed to the resolution of particular private or social problems. In that sense, economics is only one of a number of disciplines that contributes to the body of information ultimately resulting in a decision. Economists, as social scientists, thus are acutely aware of the role played by that collection of forces commonly known as the policy setting.

The contemporary concern about adequate economic research and policy analysis in the area of food protection finds its basis in the wider concern for implementation of a broad-based food policy. The changed institutional setting was summarized earlier by Howard Hjort so I will not repeat it here. However, the point to be emphasized is that public institutions are now more open in their decision making. And, like it or not, they receive comments from interested parties on almost every issue.

The setting places a strain on the bureaucracy—decisions taken must be defensible or they will not be allowed to stand. In particular, a reasonable consensus regarding

---

William T. Boehm is Acting Chief, Food Economics Branch, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture. The views expressed in this paper do not necessarily reflect the official views of the USDA or ESCS.

the likely economic impacts of a proposed rule change is needed. All the parties affected by the decision being discussed do not have to agree on the assessment, but glaring holes in the impact analyses will not be allowed to stand unchallenged.

This opening up of the public decision process has resulted in a somewhat changed role for ESCS. Once primarily involved in research related to concerns of the farm sector, ESCS is now being asked to provide assessments of policy issues spanning all of food and agriculture. The department's "food agencies"—the Food and Nutrition Service (FNS) and the Food Safety and Quality Service (FSQS)—have become important ESCS clients in recent years.

My view is that the ESCS perception of the agency's own role has changed as well. There is more concern for service, for developing a research and analysis program that contributes to better decisions on matters of importance within USDA. Certainly, other areas of work are not being aborted, but there appears to be an honest searching for an allocation of the agency's resources that will allow it to contribute more effectively as USDA's economic research and policy analysis agency.

The Food Protection Issue

The specific topic of this paper is economic research on food protection. The boundaries of that research are established, in a sense, by one's view of the word "protection." Also important is the perspective one brings to regulatory research. I argue, at the outset, for a broad-view interpretation of both.

Food protection appropriately encompasses both food safety and food quality issues. Too often, the tendency is to narrow the interpretation such that only problems dealing with immediate or short-run protections from injury or death are considered as legitimate. In such cases, many social problem areas are dismissed as unimportant or as rhetoric because the immediate health or safety aspects are not obvious. The problem with that approach is, of course, that safety itself is a relative concept.

If, for example, some foods have the potential to affect health throughout the life cycle, then perhaps nutrition education should be considered as a legitimate food protection issue. The same concept holds for product labeling, the use and revision of grades and standards, and for policy decisions on the use of food and feed additives.

In the same vein, it is moot to argue that there is "too much regulation." All organized societies operate within the confines of a generally agreed upon set of rules and regulations—some more explicit than others. The more complex a society becomes, the more explicit the rules tend to become and, simultaneously, the more pressure there is to change the rules in order to alter the present distribution of income or the flow of other benefits. Thus, deregulation is not the absence of rules, it is simply a change in the way behavior is regulated.

Such a perspective is important for conducting meaningful economic research in the area of food protection. It forces a focus on the resource adjustment implications of changes in the food protection rules—a research mold familiar to most policy analysts.

The alternative to this rather broad interpretation of the research agenda is to narrow the focus such that only economists with legal training can make an effective input. While I agree that some legal training and a thorough understanding of the legal environment are useful, I am not willing to dismiss the notion that well-trained policy analysts can make an important contribution without such a background. There are enough problems to keep agricultural economists productively occupied on food protection issues for years.

Food Protection Issues Not New

The tendency, of course, is to claim that research in this general area is new. The fact is, however, that public debates about food protection issues predate most of the major public actions dealing with farm commodity price and income support.

Federal inspection of meat began as early as 1890—as a mechanism necessary to ensure the safety of meat for exportation. Then, following publication of Upton Sinclair's *The Jungle* in 1906, meat for interstate commerce also became subject to federal inspection. The Federal Meat Inspection Act remained as the major piece of legislation regulating meat inspection until passage of the Poultry Products Inspection Act in 1957.

Those acts were designed to protect the public from unwholesome, unadulterated, or misbranded meat and poultry products. They

required mandatory, *ante-mortem, post-mortem* and processing inspection of all meat, poultry, and derivative products prepared for commerce. Today, federal inspection is also required in states which do not maintain inspection systems at least equal to the federal law.

Coincident with passage of the Meat Inspection Act was the Federal Food and Drug Act—the first federal effort in the area of food processing inspection. The Act was administered by the Bureau of Chemistry in the U.S. Department of Agriculture. In 1938, new legislation, the Federal Food, Drug and Cosmetic Act (FFDCA) was passed in order to protect the public from dangerous and unwholesome products. In 1940, administration of the FFDCA was moved to the Federal Security Agency, a predecessor to the Department of Health, Education and Welfare.

The original statute included prohibitions against poisonous or deleterious substances in food which might make it harmful to health, but did not include provisions for premarket testing of substances such as food additives, new animal drugs and/or color additives. Subsequent amendments, including the "Delaney Clause" (21 U.S.C. 348(c) (3)(A)), have been enacted to prohibit the addition to food of additives that have not been shown to be safe by appropriate tests.

In addition to these so-called food safety laws, a number of rules govern the labeling of food products. In total, these rules are designed to protect consumers from economic adulteration—fraudulent sale for the purpose of economic gain—and to facilitate trade by grouping (through labeling) relatively homogeneous product gradations.

Important in this area are the food product grades and standards programs administered by USDA. These programs are voluntary and supported by payments from the industry. Those two features, of course, distinguish the grades and standards programs from the mandatory programs of federal inspection. Additionally, most such programs were instituted to facilitate trade between producers and processors. They were not designed to communicate meaningful messages to food consumers.

Increasingly, however, there are questions regarding the appropriate role for government in this area. What discretion should be allowed if, in fact, the grades applied are used in consumer trade? Economists, it would seem, have a role to play.

The Research Agenda

The final part of this paper deals with research needs identified by the policy setting and the legal environment just described. There seem to be three identifiable areas where economic research and policy analysis can contribute significantly to the solution of problems in food protection.

The areas include the economics of information, research on the concept of relative risk and finally, policy studies to help define the consequences of proposed regulatory actions and evaluate present institutional frameworks.

Economics of Information

Most problems in the food safety and quality area relate to the delivery and interpretation of product information. In some cases, it is simply decided (by society) that the potential social costs flowing from misunderstood product information are greater than the private benefits to be derived from consumption. In those cases, product sales are prohibited.

There is also the question of "fair trade." Products are labeled to facilitate trade. If the market is to be used as a resource allocator, consumers must know what they are buying so that value messages can be relayed to producers.

Producers, too, must be protected from sales which occur in an information void. And producers of various grades of the same product do have an economic interest in labels which differentiate their products from those of other producers.

Examples in the food system are numerous. The present debates regarding "appropriate" labeling for mechanically deboned meat products, turkey ham, and imitation food products are all examples. The appropriate labeling of product weight (wet or dry tare) is another.

These are not trivial issues. They all relate importantly to the type of information needed by producers and consumers to facilitate trade. And economists have a stake in the way these issues are resolved.

Even beyond the question of "appropriate" product labeling there is the question of how consumers actually use the information provided. Presumably, the Surgeon General's warning on cigarettes was designed to dissuade product purchases. But has it? If not,

why not? Is it because consumers do not comprehend the information provided or is it because they personally are willing to accept the consequences of their purchase decision? If it is the latter, can one argue that the information has served its purpose? If it is the former, it seems to raise a research question regarding the form in which information is provided.

Surely, economists have worked on information problems in the past. But too little emphasis is being put on those problems now faced in the food sector. Since food products are purchased frequently and at relatively low per-unit costs, exploring the information trade-off between experience (using little information) and search (requiring a great deal of information) would appear relevant. Also, since food products are potentially dangerous to health, it can be anticipated that more information will lead to intensified pressures to ban products from sale. Applying economic concepts to these problems would also seem beneficial.

Concept of Relative Risk

A great deal of the present frustration with food safety and quality regulations stems from lack of an application of the concept of relative risk. As technology is developed, it becomes easier to identify small quantities of harmful compounds. Making the situation even more difficult is the fact that human beings cannot be used in scientific experiments to verify the extent of potential harm.

To date, therefore, the legal and political environment has relied almost exclusively on a concept of zero tolerance. Any evidence of harm, particularly of carcinogens, is sufficient to ban the use (and/or sale) of the product. There has been little deviation allowing for a formal incorporation of the concept of relative risk in the rule-making process.

But the political system so far has not acted. There is uncertainty about how a rule allowing incorporation of relative risk might be enforced. When does the potential social and economic harm resulting from prohibition exceed the potential harm from continued use? When are the potential health benefits worth the economic and social adjustments flowing from a regulatory action?

Economic research should be able to help answer these questions. But research on both benefits and costs is needed. Helping society clarify the concept of relative risk will require more than a set of studies that focus attention on identifiable (and measurable) costs.

Then, too, research assessing the overall consequences of additive actions is needed. Any particular action, taken by itself, may generate little measureable benefit or cost. But, when taken in total, a set of actions may well produce a significant social impact. Significant research progress will require that we learn how to deal with such additivity.

Policy Studies

In many cases, the policy debate related to food safety and quality issues could be improved significantly by a clear, concise discussion of the specific problem. While the entire scientific community has a role to play in this area, economists who understand both the political and the legal system have a potentially significant role. (Often the available options are constrained by statute—regardless of how "unreasonable" they appear. In other instances, the political setting is such that only incremental changes are possible, even if a total reform would appear to be the best option.)

One area that has received attention in recent years relates to proposals for effecting compliance with the animal drug and food additive provisions of the FFDCA. The research typically involves an assessment of the economic effects of a specific proposal to alter regulatory procedures. Studies assessing the impacts of restricting the use of animal growth hormones, antibiotics and food additives are examples.

The continued subtherapeutic use of some chemicals is being questioned because of scientific evidence linking resistant strains of certain organisms to the chronic intake of antibiotics. The development of such resistance is of concern because it makes the drugs potentially less effective in dealing with human health problems. Other drugs are being proposed for use restrictions because they have been found to produce tumors in laboratory animals.

While all producer advocacy groups have strongly opposed such regulatory changes, the available research indicates that the proposals would likely have little noticeable effect on resource use in the aggregate. Indeed, since the demand for most agricultural products is inelastic, the short-run effect of a unit-cost

increasing action is to increase industry revenue.

An immediate ban on the use of nitrite to cure bacon, for example, would create the need for some adjustments. Hog prices would fall—about $2-3 per hundred weight—reflecting the fact that large quantities of pork bellies would have to be rendered into lard. Food prices, though, could be expected to increase, in the longer run, because of the higher pork processing costs and the increased demand for substitute meat products. While the adjustment cannot be termed as disastrous, there is a possibility, at least initially, that some hog producers would go out of business.

But cattlemen would probably benefit from such a ban. Because of the increased demand for beef products, cattle producers' receipts could be expected to increase. If there were a total ban on the use of nitrite in the curing process, cattlemen potentially would stand to gain even more since only about 10% of all beef is now cured with the chemical—over 55% of all pork is now nitrite cured.

The interesting story that unfolds from most of these studies is that it is consumers rather than farmers who end up shouldering the impact. Food prices tend to rise, but aggregate farm income either increases or remains about unchanged.

Do consumers really end up worse off? If these actions do have the effect of improving the nation's health, then perhaps it means higher food costs, but lower costs for medical care.

Policy research in this area must initiate as well as respond. Over the years, agricultural economic research has played an important role in shaping policy. Parity price support programs, land diversion schemes, and food distribution programs were all influenced in important ways by researchers who had a vision of the need for alternatives and then did something about it. Future research programs in the area of food safety and quality should build on that tradition.

Efficiency of Present Systems

Apart from the questions related to specific policy issues and program options is the need for evaluation of present systems. The broad social objectives in an area tend to be specified in the statutes. In almost every case, responsibility for the administration of programs designed to achieve those objectives is lodged with the federal bureaucracy. Once in place, there is an important continuing need to assess the relative performance of the system.

There are essentially two questions that need to be addressed by the research.

(*a*) Is the present (or proposed alternative) system effective? (i.e., does it work?), and

(*b*) Is it efficient? (Are the programs being administered in a cost-effective way?).

The effectiveness question is difficult to research. We almost never have a benchmark. Most will agree that the food supply should be safe—that the public should be protected from the deliberate or even unintentional sale of foods that will cause death or disease. But putting this protection into operation is a program question. And alternative programs produce different results at different costs.

Quite often there is little or no opportunity for controlled experimentation. But that does not negate the importance of or the need for research in this area. Decisions will be made and economists would seem to have a responsibility to provide information about the likely resource use impacts associated with alternative program options.

Program efficiency studies are probably easier to do but are no less important. Efficiency, of course, is measured by the degree to which present organizational structures achieve a given level of service. Questions about administrative costs relative to the task being performed, and appropriate sampling for a given level of accuracy are both important aspects of the research needs in this area.

The obvious difference in inspection philosophy between USDA and the Food and Drug Administration (FDA) is an excellent example. The FDA approach is less labor intensive and is based more on sampling. "High risk" operations are visited most often but, even then, there is no inspection of each food item. USDA's procedures now require the actual physical inspection of each carcass. The system is labor intensive. What would alternative systems cost? What would be the probability of reductions in the safety of the food system? How might the present system be changed to improve the delivery of services and perhaps reduce costs? In an age when inflation pressures are foremost in the minds of policy makers and most citizens, it would seem that economic research addressing the simple question of how efficiently government ser-

vices are being performed could have high payoff.

Concluding Thoughts

This paper has been developed to spark discussion. The research agenda is not project-specific but rather covers the broad areas of needed research.

Agricultural economists have done such research in the past. Some are working in these areas at the present time. But more and better research is now needed. Decisions in the area of food protection policy are being made. Whether we contribute as a profession is our choice.

If we decide to do more in this area, we too will be faced with a resource allocation problem. Some resources will undoubtedly have to be allocated to longer-term work on the conceptual issues like information and relative risk. Such work is needed. But the shorter-term policy studies will continue to be needed as well. The historical cooperative working arrangement between ESCS and universities provides the institutional setting for getting both jobs done. Hopefully, the work will proceed at a relatively rapid rate.

Price and Income Policy Issues

Preston E. Laferney and J. B. Penn

In this paper, we develop the concept of price and income policy as a sub-set of the larger set of regulation policies. It follows, therefore, that price and income policy research is an integral part of regulation research as discussed at this conference.

The Scope of Regulation Research

Regulation can be viewed narrowly, as agricultural economists have tended to do—one specific issue at a time. Setting quality standards for one product—wheat or beef—and operating an enforcement system is an example of a specific, narrow issue. Or, regulation can be viewed in a much broader sense. The broad view encompasses all government interference or involvement inside or outside the market system, regardless of the specific objective. Objectives vary widely from income redistribution (a primary goal of price and income policies) to specific social goals arising from market failure (such as maintenance of environmental quality) to those essentially not market oriented at all (tax policies, for example).

The semantic arguments we get into over what constitutes regulation research as distinct from other research (policy and other kinds) are in the main unnecessary—they are probably counterproductive unless the varying views which give rise to the arguments are hindering the identification of important issues and the scope of our total research efforts. We feel that the real need is to air the issues in fora such as this conference, not just tc "define" regulation research, but to move us toward a closer integration of all regulation (policy) research.

Agricultural Price and Income Policies

Price and income policy in agriculture is concerned, among other things, with the redistribution of incomes to achieve specific social goals. The goals arise not so much from a market failure as from society's unwillingness to accept the adverse adjustment effects that would be accomplished through the operation of a free market. With society unwilling to leave the market free to make the adjustments in agriculture, the objective has been to achieve an income redistribution through government intervention while minimizing the resulting economic inefficiency.

Price and income policy formulation involves trade-offs. As we examine these trade-offs, we begin to see the interrelation between price and income policy and other kinds of regulation. Some of these trade-offs are:

(*a*) Between large, medium, and small farmers. These units are all within the agriculture sector, but nonagricultural regulations, such as tax policy affect income distribution among them.

(*b*) Between grain and livestock producers. Again, both groups are within agriculture, but other regulations, such as control of point source pollution, affect their relative income positions.

(*c*) Between the freedom of individual decision makers and the extent of government involvement in production and marketing decisions. This trade-off, by definition, is true of all regulations.

(*d*) Between producers and consumers. Here, one begins to see the interdependence of farm and nonfarm sectors. For example, a ban on nitrites in bacon would affect the two groups differently.

(*e*) Between segments of the food system—producers and processors, for example. In crop set-aside decisions, decreased volume of production is detrimental to processors and beneficial to producers.

(*f*) Between taxpayers and producers. The concern with Treasury outlay effects of price and income policies for agriculture is a prime example.

(*g*) Between domestic policy and foreign

Preston E. Laferney is Acting Chief, Crops Branch, and J. B. Penn is Deputy Administrator for Economics, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture.

policy objectives. Higher domestic support prices tend to reduce the volume of our foreign trade.

(*h*) Between sectoral or microeconomic objectives and macroeconomic objectives. Examples are higher commodity prices for farmers versus inflation, and Treasury outlays to help farmers versus the budget deficit.

What is the point of discussing a traditional area like price and income policy at a regulation research conference? This is a research-oriented conference—its purpose is to stimulate interest in regulation research, to identify issues of high priority for future research and to identify information needs that can be met by research for public policy discussion and formulation.

Our primary point of emphasis is to argue for a more comprehensive perspective in research planning—to suggest that price and income policy research and analysis cannot be done well in isolation from other regulation research and vice versa. In food and agriculture, whether the broad view of regulation (policy) research is accepted or whether a more narrow view is preferred, the interdependence of governmental actions—both inside and outside the marketplace—must be treated simultaneously. They must be analyzed in the real world context as they operate in conjunction with one another. We submit that informed public policy debate and its formulation requires this—that fragmentation and partial analyses may provide misleading results and prove to be a disservice to our immediate clients and to the public interest.

Conditions Requiring a Comprehensive Perspective

Price and income policies—in fact most all regulatory policies—are formulated to meet relatively narrow objectives. The attendant programs focus on the means of achieving the stated objectives. For price and income policy, this was not grossly inappropriate for many years—the farm sector was *not* closely interrelated with the domestic economy.

This is no longer true. Agriculture, by virtue of increased instability, which arises to a great extent from the increased dependence on foreign markets, now transmits that instability to the entire domestic economy. And, the changed structure of the food system means the performance of the domestic economy now has much more influence on the food and agriculture system. This is evidenced by the following characteristics:

(*a*) Farmers are still price takers. The farm sector is sandwiched between the input-supplying and food processing and distribution sectors, both highly concentrated and able to influence prices—to pass through cost increases. Thus, developments in these sectors, whether changing wage rates in the labor market or government regulations, eventually have an impact on the farm sector. This is not new.

(*b*) But, other things are changing: There is a growing industrialization of the farm sector—it is now big business; there is an increased reliance by agriculture on inputs purchased from the nonfarm economy—something like 70% of the total at present; there is a growing capital intensity within the agricultural sector; there is an increased use of nontraditional exchange arrangements—integration and coordination; there is a shifting within the cost structure toward more fixed relative to variable costs; and there is the ever-present phenomenon of increasing land prices.

(*c*) Also, the increasingly greater proportion of the food dollar accounted for by nonfarm inputs represents a significant change. Something like 60% of the total expenditures for domestically produced food is for inputs and services other than the raw material (commodities) provided from the farm.

Increasingly, regulatory actions in the food system and in other sectors of the economy significantly affect the farm sector. These regulatory actions, even individually, and certainly in concert, often have effects that offset or enhance those of the more narrowly formulated price and income policies.

Price and income policies, as well as other regulatory policies, may have unintended and undesirable indirect consequences, or even direct consequences, when all policies operate at the same time. As an example, consider the escalation of target prices based on cost of production estimates. Environmental Protection Agency, Occupational Safety and Health Administration, and Federal Grain Inspection Service regulatory actions directly or indirectly affect the cost structure of farms. They either increase costs, causing target prices to subsequently increase and programs to become more expensive, or they affect one type or size of farm relatively more than another,

giving a competitive advantage to certain types and sizes of farms relative to others.

Today, there are other regulatory policies that may be having an equal or greater impact on the structure of agriculture than are the price and income policies, even though these effects usually are much less direct and less obvious to most observers. For example:

(*a*) Transportation policy: trucking industry deregulation, Interstate Commerce Commission rate structures and rules, waterway user charges, rural area rail line abandonment, and others.

(*b*) Tax policy: rate structures, accounting rules (cash versus accrual), capital gains treatment, inheritance tax provisions, use value taxation, property taxes, and others.

(*c*) Energy policy: natural gas deregulation, deregulation generally, priority fuel allocations, and others. These bear a close relation to cost of production, thus to price and income policy.

(*d*) Macroeconomic monetary and fiscal policies: the growth policy, anti-inflation program, changes in the money supply (interest rates), the balanced budget goal, and others.

(*f*) Alien investment—generally and in agricultural land specifically.

(*g*) International commodity policy.

(*h*) International trade policy.

A Structure Policy for Agriculture

The structure of the farm sector is an issue now being widely discussed. There is a growing, if not general, consensus that the price and income policies and specific commodity programs, over time, have produced unintended and unwanted consequences. Even though the preamble to every farm bill enacted since the 1930s has contained the explicit objective of helping the family farm, these policies, in fact, may have served to hasten its demise. What segments of agriculture benefit most from agricultural policies? What are the structural effects of these policies over time? What kinds of policies can be designed to assure a viable agricultural sector in some proper balance with other sectors over time?

The discussion above serves to point out that should an explicit structure policy be pursued, price and income policy will be but one component among many, and perhaps a relatively minor component. All the areas noted above, plus several others, will be integral parts. Each has a significant bearing on the structure of agriculture and on the well-being of those who farm.

The import of this for us, and the message of this discussion, is that our research on policy alternatives must be more all-encompassing in the future. To be adequately researched, all regulatory (policy) alternatives must be considered as they operate in conjunction with one another.

Economic policy issues are seldom simple. They are complex now and will become more so as the arguments above indicate.

The Secretary of Agriculture has placed the formulation of a new structure policy on his—and our—high priority list. To meet the need he perceives will require that we think about much more than just traditional price and income policies. Regulation research in its broader sense, as discussed in this conference, must be integrated with traditional price and income policy research.

Product Market Regulation: Implications for Research

John W. Helmuth

The purpose of this conference—to serve as a catalyst for further research on regulatory issues in the U.S. food system—requires going beyond safe, familiar ideas. It gives us an opportunity to broaden our perspectives. If an idea is of significance, people who hear of it will reflect on it, take it apart and accept it or reject it. My objective is to put forth some ideas which will create that kind of response.

I will begin by summarizing possible methodological approaches to economic evaluation of regulation; then I will highlight the existing areas of product market regulation; mention some of the current areas of controversy; and conclude with some recommendations for research.

Economic Evaluation of Regulation

I define "product market" regulation as federal involvement in any or all aspects of the marketing of food or fiber commodities in the chain from producers to final consumers.[1] Evaluating the economic effectiveness and/or impact of regulation immediately brings benefit-cost ratios to mind along with all the attendant measurement problems. Direct costs of federal regulation are the easiest variable to measure—they, of course, are the federal costs of administering a particular regulatory program. Other indirect and/or social costs are much more difficult to quantify as are the direct and indirect social benefits.

Possible approaches to estimating benefits and costs include market structure, conduct, and performance comparisons before and after regulation or between similar marketing channels with and without regulation. Unfortunately, such approaches are plagued with the difficulty of realistically applying the *ceteris paribus* assumption.

On the less quantitative side, it is interesting to consider more subjective measures which might be termed content/discontent ratios or possibly a compliment/complaint ratio. Such measures certainly give a feel for how a particular industry or group views the effectiveness of the regulatory process, but must be used cautiously. Different industry segments—producers, middlemen, consumers—generally will have different perspectives which usually lead to different compliment/complaint ratios. Such ratios take on more meaning as experience with a given body of regulation develops over the years and are less useful during the uncertain period when a new area of regulation is being considered.

Existing Product Market Regulation

Federal product market regulation relating to food and fiber can be grouped under the following headings: safety and quality assurance; protection against misrepresentation of products or unfair business practices; and industry self-help programs.

Safety and quality assurance regulations generally fall under the Food Safety and Quality Service of the U.S. Department of Agriculture (USDA) as well as the Food and Drug Administration (FDA) of the Department of Health, Education and Welfare (HEW).

Regulations dealing with protection against product misrepresentation or unfair business practices fall under the Agricultural Marketing Service (AMS) of USDA, the FDA and the Federal Trade Commission. In addition, independent regulatory bodies such as the Commodity Futures Trading Commission administer laws dealing with transaction integrity.

Each of these regulatory areas could provide the basis for a detailed analysis of the economics of regulation. However, in order to

John W. Helmuth is an economist with the Committee on Small Business, U.S. House of Representatives, Washington, D.C. The views expressed are solely those of the author.

[1] The author excludes state regulations to limit the scope of the discussion.

limit the scope of this paper, I will concentrate on the last area of regulation—industry self-help programs.

In this category I group the commodity research and promotion programs (check-off programs) and the marketing order programs of AMS. The common characteristic of these programs and the reason for the term "self-help" is that, under enabling legislation, such programs only come into existence if the affected industry voluntarily chooses to have them in referendum.

The research and promotion programs might be termed quasi-regulatory since the only federal involvement other than administrative oversight is to enforce collection of fees to be used for research and promotion efforts. Interesting questions can be raised regarding the benefits and costs of the generic advertising aspects of these programs, particularly with respect to food commodities and in light of the fixed size of the "American stomach." What is gained, from society's point of view, in having orange juice compete through advertising with tomato juice for a place on the breakfast table? One has to wonder if the advertising agencies might not be the only ones realizing long-run net gains.

Approximately $140 million was spent by all programs combined on research and promotion in 1972 (Parlett and Henderson). The majority of such expenditure goes for advertising. The significance of this issue takes on a new dimension when one considers that the beef research and promotion program currently under consideration would generate an estimated $60 million in revenues. Microeconomic studies have been done on the impact of advertising for particular commodities (Thompson), but what is sorely needed is a careful analysis of both the short- and long-run costs and benefits for all commodities viewed as a group. Only then can meaningful social decisions be made regarding the worth of existing and future promotion programs.

Marketing Orders: Successful or Inflationary?

As a self-help program, marketing orders are legal instruments authorized by Congress in the Agricultural Marketing Agreement Act of 1937. They serve as a means through which farmers can organize to market their product, increase their bargaining strength in the competitive-oligopsonistic markets in which they sell and generally work together to solve marketing problems they cannot solve individually.

Marketing orders are currently prominent in the fruit, vegetable and dairy industries. Their broad objective is to achieve "orderly marketing" by regulating in some way the flow of raw commodities into the marketing system. Specifically, this currently is achieved by using the following methods: (*a*) smoothing the flow of commodities to avoid gluts and shortages; (*b*) specifying minimum quality standards; (*c*) standardizing quality, size or packing requirements; and (*d*) in the case of milk, establishing minimum prices handlers must pay producers according to the use made of the milk, pooling proceeds on a market-wide basis, auditing of receipts and utilization, verifying weights and tests and providing market information to all parties (USDA, p. 1).

The marketing order decision-making process reflects the views of producers, handlers and consumers with final authority resting with the Secretary of Agriculture (USDA, p. 1).

In the current budget-cutting, inflation-fighting economic climate marketing orders have come under renewed attack as potential contributors to inflation. The budding controversy surrounding orders is addressed in the next section.

Controversy over Marketing Orders

The health of the American economy is significantly dependent upon a sound, healthy agricultural sector. Maintaining a healthy agricultural sector can be achieved only if we set an equitable rate of return to agricultural production as a primary social goal. Given the unavoidable uncertainties of such production and assuming as a goal the maintenance of the family farm, an equitable rate of return can be achieved in two primary ways: (*a*) by government use of tax revenues for income programs employing various methods to restrict production and establish price floors; or (*b*) by recognizing the inherent competitive-oligopsonistic nature of agricultural markets and the need to provide farmers with self-help tools to countervail the economic power over price held by buyers of raw agricultural products. In other words, the government can attempt to ensure farmers an equitable rate of return and/or the government can create a climate in which

farmers can do it themselves. By allowing farmers to organize for marketing and bargaining purposes, some movement toward countervailing economic power can be achieved and the concept of the family farm is maintained.

If one accepts this line of reasoning then one is placed in apparent conflict with consumer interests, recognizing that consumer interests are characterized as desiring a high quality, wholesome, reliable supply of food and fiber products on a year-round basis at the lowest possible price.

Current attacks on marketing orders are coming from two directions with two levels of intensity. At the lower level of intensity the National Commission for the Review of Antitrust Laws and Procedures recently recommended that the Secretary of Agriculture be required to take competitive factors into account and to choose the least anticompetitive alternative consistent with statutory goals when marketing order decisions are made. The Commission's recommendation suggested that there is an explicit antitrust exemption for marketing orders in the Agricultural Marketing Agreement Act. However, the Act itself is an exception to antitrust laws and it should be clearly understood that any review of the antitrust status of marketing orders is really a review of whether the Agricultural Marketing Agreement Act should be retained in any form.

With respect to the specific recommendation concerning marketing orders, the Department of Agriculture's current rule-making procedures provide a framework for the consideration of competitive factors based on evidence presented at formal hearings. The hearings help to ensure the selection of the least anticompetitive alternative consistent with the record of evidence and the statutory goals of the Agricultural Marketing Agreement Act.

Even though the statutory goals of market orders recognize that it is socially desirable to restrain destructive price competition, the Commission's recommended requirement could place the Department of Agriculture in the position of proving this over and over in the day-to-day exercise of its responsibilities in administering marketing orders.

Carrying out the intent of this recommendation could cause much misunderstanding and controversy because of the apparent conflict with the statutory goals of marketing orders. Market orders were designed to put agricultural producers on a more equal footing with large buyers and thus achieve a greater degree of price competition between buyer and seller. This was done through provisions which restrain destructive price competition between individual farmers.

A more intense attack on marketing orders is coming from the President's Council on Wage and Price Stability. As part of their laudable effort to control inflation, the Council is seriously questioning the need for marketing orders. The Council's approach is based on short-run consumer interest. It implicitly assumes that short-run commodity price increases are inflationary regardless of longer-run trends and does not properly consider the long-run implications of doing away with marketing orders. The Council's approach has been to bring the marketing order decision-making process under review via Executive Order 12044 which calls for economic impact analysis of Executive Branch decisions.

Even though Executive Order 12044 exempts marketing order decisions made under the formal rule-making procedures of the Administrative Procedures Act, the Department of Agriculture, under the Secretary's Memorandum Number 1955 has included these decisions in the requirement for impact analysis. Through this mechanism the Council has been strongly questioning any decision which has any price-enhancing aspects. One must ask whether such an approach is consistent with the statutory goals of the Agricultural Marketing Agreement Act.

Are marketing orders inflationary? Evidence to date on fruit and vegetable orders indicates that most orders regulating grade and size of fruits and vegetables have no significant price-enhancing results. In addition, while quantity control programs have inherent price enhancement capabilities, they have increased price stability and have thus stimulated production of the affected commodities beyond levels which could be expected without such orders (USDA). Evidence for milk orders indicates: (*a*) Since milk orders have no provision for control of supply, any efforts to maintain prices at levels higher than warranted by supply-demand conditions tend to be self-defeating; (*b*) While the federal milk order program establishes minimum prices, the system plays essentially a passive role in price change; (*c*) Milk order prices fluctuate in a fixed relationship to competitive prices in the manufacturing milk market; (*d*) These man-

ufacturing prices, in turn, are influenced by supply-demand conditions in the dairy industry and by government dairy price support policy; (*e*) the dairy price support program is the primary factor influencing federal milk order prices at the present time—if current prices are too high, the appropriate vehicle for reducing them is the price support program, not the marketing order program.

Are minimum prices set under milk marketing orders inflationary? Consumer prices for fluid milk have risen substantially less in the last ten years than the index of prices paid for all foods or the aggregate of the consumer price index. This longer-run trend may indicate that pricing under milk orders has not contributed substantially to inflation in food prices. Also, milk orders have helped maintain adequate supplies of high quality milk for consumers. This has served to keep prices down.

Higher farm product prices may appear superficially to be inflationary. But when the higher price is associated with a higher quality product, or a more stable, year-round supply the consumer is getting a better buy.

Why not abolish marketing orders? Because orders generally are not inflationary, and do help solve marketing problems. They contribute to market stability and efficiency. This is beneficial to the public, both to producers and consumers. Orders promote long-run stability in supplies for the consumer and in income for the farmer, both of which are obviously more desirable than the boom-bust cycle that might otherwise prevail.

If marketing orders were abolished, what would be the consequences? In the absence of marketing orders, some or all of the following consequences might be expected: wider price swings; more bankruptcies; more variability in quantity and quality supplied; higher government spending on commodity support programs; a greater reliance on commodity imports; farmer cooperatives strongly motivated to attempt to control the amount produced; and an accelerated trend toward corporate agriculture.

The long-run dangers of taking a short-run view of marketing orders and striving to stop any price-enhancing aspects of orders can be illustrated with reference to a recent study by Hammond, Buxton and Thraen. They indicate that, by changing the current milk marketing orders to allow for the pricing of reconstitutable milk at less than Class I prices, which would make inter-order shipment of reconstitutable milk economically feasible, retail milk prices could be expected to advance approximately 1¢ per gallon in the Lake states, and 2¢ per gallon in the Southwest while declining 2¢ per gallon in the Northwest and 14¢ per gallon in the Southeast. A slight increase in the price of manufactured dairy products also is predicted. Superficially, this might appear to represent, from the consumer viewpoint, a socially desirable change in the orders.

But what of the long-run consequences? One may observe the waste involved in shipping heavy, high volume grain all over the country on an outdated, crumbling rail system to supply feed to dairy farms and consider action to concentrate dairy production near input supplies. However, this would imply some severe production shifts. What would be the social cost of displacing thousands of farm families? Would viable alternative employment be available to them?

What are the indirect social benefits of prosperous dairy farms in Connecticut or Florida? Of what social value is the family farm a hundred miles from New York City? What are the total costs of shipping feed grains from the Corn Belt to the Eastern Seaboard? How do these compare to retail prices a few cents per gallon lower? What does 5¢ per gallon mean as a percentage of consumers' disposable income?

The Potential for New Orders

The current attack on orders may be the best available indication of the success of the marketing order program. To the extent that orders have been successful in accomplishing their purpose of coordinating agricultural marketing activities at the producer-first handler level and achieving an orderly marketing system; to the extent that they have stabilized the flow of product and avoided gluts and shortages; to the extent that they have helped maintain product quality and promoted standardization within marketing channels; and to the extent that they have helped stabilize product prices and producer income, they can be considered one of the most successful agricultural regulatory programs. If this is true one must wonder about the potential for marketing orders in commodities other than fruits, vegetables and milk.

What is the potential for orders in grains and livestock? Critics of such an idea immediately point to the diversity of cost structures, geographically dispersed production areas and sharply differing producer viewpoints in these commodities. They point out that much of the success of orders is dependent upon the relatively confined nature of fruit and vegetable production where producers are strongly bound by common interests. In response, I would point to the nationwide system of milk orders which share many common characteristics but yet remain flexible enough to deal with the unique problems of a given geographic area. Has the time come for this concept to unite grain and/or livestock producers?

Farm groups are calling for "a bushel of wheat for a barrel of oil" in response to increasing crude oil prices. Grain exports have become a significant positive element in our balance of trade. Those who advocate using our grain exports for leverage against high crude oil import prices are suggesting a government grain export board to withhold exports until higher prices are achieved. Not withstanding the moral question of using food as a international bargaining chip, the merit of such an idea hinges on the extent of the inelasticity of demand for U.S. grain exports.

A grain marketing order should be seriously considered in lieu of a government grain export board. Such a marketing order would leave the decision power in the hands of the producers; it could possibly provide countervailing power for producers against the multinational grain companies; and it might reduce the USDA budget for support payments and remove the government from a direct decision role regarding the production and marketing of grains.

Research Implications

I see a need for research in several areas. I previously mentioned the need for a macroeconomic benefit-cost look at the research and promotion programs.

In addition, the entire fruit, vegetable and dairy marketing order complex needs careful evaluation to measure, where possible, the short- and long-run benefits and costs. Some of the work being done is a start in the right direction. But if new substantive evidence weighing on the current inflation question is to be obtained, a much larger, coordinated research effort is needed.

In my opinion, the time has come to carefully study the feasibility of marketing orders in grains. The information imbalance in international grain trading resulting from U.S. producers voluntarily providing estimates of U.S. supplies while multinational grain companies keep export demand information secret sets the stage for significant redistribution of returns to increased producer market power. Estimates of the redistribution effects along with estimates of the costs of an order program compared to present government support program and other USDA costs are needed to form the basis of benefit-cost analysis of the marketing order alternative.

A marketing order for grains might be viewed as acquiescing to oligopsonistic market power by establishing some degree of monopoly power on the part of the farmer. But what is the likelihood of significantly reducing the oligopsonistic power of the multinational grain firms through government action? For instance, is it possible to provide accurate, timely and complete export demand information to farmers so that their selling decisions can be made with as much knowledge of demand as their buyers have regarding supply?

A significant research opportunity exists to study the present grain trading system from a pricing efficiency and resource allocation point of view and to compare it to the potential which might be achieved by obtaining accurate, timely and complete information on U.S. export sales. How much does it cost U.S. producers to sell into a market where supply information is public knowledge and export demand information is secret? Given the resultant price uncertainties from such a market, what are the total costs of incorrect resource allocation decisions? If complete export sales information were mandated how would this impact on U.S. export sales? If export sales declined as a result of requirements for increased demand information, would the aggregate export revenues lost be less or greater than the aggregate revenue gains to producers from improved marketing decisions plus the gains resultant from improved resource allocation? Who would gain or lose from a change toward the perfectly competitive model via improved market information?

A marketing order for grains probably would not generate more information regarding demand and might result in less supply

information if farmers viewed such a move as beneficial to their position under an order. How then would an order compare to the present system or to an environment of mandated, comprehensive export sales reporting?

Panel Discussion[2]

Robert W. March. The milk order program is one in which agricultural economists have played an important role since its inception. Many of the changes in orders have been based on their recommendations. I know of no other government agricultural program where agricultural economists have participated in the program development process to the extent they have in the milk order program, or where economic analysis has been used so extensively. The milk order program has attempted to utilize the tools of agricultural economics to bring order and stability to milk marketing. The program has numerous elements that have stimulated the interest of economists—price discrimination, pricing formulas, location differentials, pooling, and other unique aspects to tempt the imaginative researcher. There are forty-seven orders spread throughout the nation. Orders provide detailed information by markets regarding sources of milk, sales, intermarket shipments, plant locations, and prices, which greatly facilitates research.

Charles R. Brader. Dr. Helmuth's vision of the social role of marketing orders certainly runs counter to the general comments lately being directed towards these programs. I do not envision expansion of these programs as a panacea for the supply-demand problems which U.S. farmers have been confronting for many decades.

The forty-seven federal marketing orders for milk have a common means of advancing their orderly market objectives. Many perceive fruit and vegetable marketing orders to be similarly uniform. However, this is not the case. There are currently forty-seven marketing agreement and order programs in effect for commodities other than milk, covering more than thirty commodities. Many of these programs use quality control provisions to effect orderly marketing. In fact, this is the most common type of fruit and vegetable program. However, various forms of quantity control such as flow-to-market regulation, market allocation, and producer allotment provisions, are also used. Provisions for container requirements, production research, marketing research, and promotion are common.

Better understanding of these programs would eliminate most misconceptions. For example, many people perceive a strong interdependence between fruit and vegetable marketing orders and cooperatives. However, a little study would reveal this to be an erroneous generalization. It would be helpful if university agricultural economists would develop marketing order expertise in the fruit and vegetable sector.

Regarding Dr. Helmuth's comments on the research and promotion programs and the "fixed-stomach-size" theory, the fundamental idea cannot be refuted. But I believe it is an overly simplified argument. We in agriculture would not advocate the advertising of orange juice to replace tomato juice on the breakfast table, as in Dr. Helmuth's example. But we could quickly find social value in substituting orange juice for soda pop or other highly sweetened, flavored drinks. Likewise, we can find social benefit when grapes and raisins are advertised as snack foods in lieu of sweets.

I agree that a careful analysis of both short- and long-run costs of such programs is in order. There is no argument that social costs may be considerable. I merely wish to point out that there may be social benefits as well.

Edward V. Jesse. Helmuth's remarks provide the basis for numerous comments. I will limit my remarks to three areas.

In the past I have proposed that generic advertising programs prompt countervailing promotion activities on the part of competing commodity producers. This results in only transitory demand increases and a higher cost structure in the long-run. In addition, free rider problems are inevitable.

Proponents argue that these are consumer education programs. The benefits of these programs may be substantially less clear than suggested by Helmuth. Consumer education and information programs may be highly beneficial to society and producers, without cutting back consumption of competing agricul-

[2] Ed. Note: Helmuth's presentation included a formal panel discussion. Discussants were: Robert W. March, Dairy Division, Agricultural Marketing Service (AMS), U.S. Department of Agriculture (USDA); Charles R. Brader, Fruits and Vegetables Division, AMS, USDA; Edward V. Jesse, National Economics Division, Economics, Statistics and Cooperatives Service, USDA; and Ted Moriak, Office of Budget, Planning and Evaluation, USDA.

tural products. There may be a high payoff to studies of individual programs. We know too little about generic advertising in general to properly study the gross impacts of all programs as a group. But few agricultural economists seem willing to conduct the studies necessary to appraise the potential success of specific generic programs.

Glaringly absent from Helmuth's short list of possible ways to achieve an "equitable" rate of return to agricultural production is more stringent enforcement of antitrust laws. If agricultural markets are inherently competitive-oligopsonistic in nature, actions to remove competitive barriers on the buyer side of the market would (at least superficially) appear to be more efficient than actions designed to make the seller side of the market less competitive.

Helmuth outlines directional changes in measures of market performance consistent with the abolishment of marketing orders. Few would argue about these changes. But their magnitude is of substantially more critical concern. Specifically, would aggregate negative impacts from abolishing orders exceed the benefits of removing constraints to competitive resource allocation? I have much more faith in the "free" market system than implied by Helmuth's discussion.

On the other hand, I fully concur with Helmuth's observation that the social impacts of orders and other regulatory programs are of very high concern. Unfortunately, these are typically ignored in analyses of marketing orders and other regulatory programs. The effects of marketing orders on the structure of the production sector is especially important. A fundamental farm policy question concerns the kind of farming structure desired by society. If such a desirable structure can be identified, research on marketing orders and other types of regulatory programs must focus on how these contribute to or detract from this desirable structure.

Ted Moriak. The Secretary's Memorandum No. 1955 expressed a belief that the Department should minimize unnecessary burdens on the public while achieving maximum effectiveness from all decisions including regulations, agency directives, legislative proposals and reports, and other program actions. Consequently, the USDA decision system is more comprehensive than the President's Executive Order 12044 for improving government regulations, and provides authority for policy analysis of price impacts as envisioned by an Interagency Task Force several years earlier.

The analysis regards meaningful alternative actions as selected by policy officials. Impacts are estimated on employment, prices, competition, terms of trade, production and utilization, input markets, energy use, resources, technology and productivity, investment, credit supplies and taxpayer costs for USDA and other Federal agencies. Social impacts on health, safety, nutrition, civil rights, institutions, and invasion of privacy should be estimated. The geographic concentration of the impacts, the distribution through time, and the effect on income classes or size of business operation within each of the impacted groups need consideration. Although benefit cost ratios and internal rates of return may be included, the decision need not rest solely on their ranking.

The timing for conducting policy analysis under the formal rule-making procedures used in market order decisions is critical. *Ex parte* communications are in effect from the time of the notice of hearing through the final decision. The final decision must be based entirely upon evidence presented at the hearing. Frequently, studies exist, but the material may be outdated or the witnesses do not fully understand its importance. Thus, such work is ignored in decision making.

The department is developing a procedure for pre-hearing investigations. It will describe the issues, the alternative actions and list the range of estimates on the important consequences which have appeared in various professional studies, prior to the notice of hearing. If an important analysis is not included in the prehearing investigation, then the researcher should come to the hearing and explain the analysis in order that it be considered in the decision.

References

Hammond, J. W., B. M. Buxton, and C. S. Thraen. *Potential Impacts of Reconstituted Milk on Regional Prices, Utilization and Production.* University of Minnesota Agr. Exp. Sta. Bull., in press.

National Commission for the Review of Antitrust Laws and Procedures. *Report to the President and the Attorney General.* Washington, D.C., 22 Jan. 1979.

Parlett, Ralph L., and Peter L. Henderson. "Promotional Activities of Agricultural Promotion Groups." USDA ESCS Working Paper, 1977.

Thompson, Stanley R. *An Analysis of the Effectiveness of Generic Fluid Milk Advertising Investment in New York State.* Cornell University Agr. Exp. Sta. Res. Bull. No. 78–17, Sept. 1978.

U.S. Department of Agriculture. *Price Impacts of Federal Market Order Programs.* Farmer Cooperative Service, Report of the Interagency Task Force, Special Rep. No. 12, 7 Jan. 1975.

Environmental Regulation: A Framework for Determining Research Needs

Wesley D. Seitz

I assert that there is now and will continue to be regulation of the food system directed toward the attainment of environmental objectives. While some may make a persuasive case for reduced regulation, I submit that the number of people favoring elimination of all environmental regulations affecting agriculture is a very small minority indeed. And we, as economists, using concepts such as market failure, externalities, and public goods (or bads), can explain why quite easily. We can demonstrate that society is better off if government constrains the private sector than if it does not.

Of course, it is impossible for agricultural economists or others to determine a perfect level of intervention because we do not have a social welfare function. But my purpose is not to provide a lesson in welfare economics; it is to give the audience a means of identifying important research areas relating to environmental problems. I am not going to share the list of specific research problems which strike me as interesting, rather I am going to lay out a framework for your use in determining where important research problems are likely to be found. But first I am going to outline the nature of the beast we confront and the implications of working in this area on the client relationship between the agricultural research community and the private sector.

The Environmental Problem

From an economic perspective the environmental problem is one of market failure or externalities. The classical case occurs when a pollutant is generated in the process of producing a normal economic good. The pollutant is discharged into the environment where it reduces the profit or satisfaction of others. It has been demonstrated that in the simple two-person case a mutually beneficial resolution can be achieved through a bargaining process. However, these simple cases are rare exceptions. In the common case, many farms, firms, and individuals generate varying mixtures of pollutants which impact receiving farms, firms, and individuals with varying consequences. Most of the consequences are negative, but there are cases where some benefit from the pollutants.

Two additional factors complicate the problem. First, in many cases the adverse impacts occur in the future, often beyond the time horizon suggested by a social, and certainly the current market, discount rate. These impacts can be considered externalities between generations. Reservoir siltation, the accumulation of pesticide residues, the development of pest resistance, the delayed development of cancers, and the loss of productivity due to erosion are examples of delayed impacts. A second complication results from the fact that the economic value of each pollutant is often small relative to the value of the normal good with which the pollutant is associated. In addition, each contributor to the pollution problem often adds but a small portion of the total and each receiver incurs a minor share of the damage. It is through processes of aggregation and accumulation that a problem becomes large enough to warrant attention and sufficiently complex to make private sector bargaining solutions unrealistic. Because the aggregated effects are external to the individual or firm, environmental regulation appears unwarranted to individual agents.

Due to these characteristics of pollutants, little data exists on the quantities produced, the locations of production, the movement of the pollutants, and the extent of damages done. This lack of data requires that the economist work closely with physical and biological scientists to generate estimates of the quantities involved, their sources, and their impacts. From such estimates economists can

---

Wesley D. Seitz is a professor of agricultural economics and associate director, Institute for Environmental Studies, University of Illinois, Champaign-Urbana, Illinois.

attempt to estimate values that will be useful in making policy recommendations. Of course, these values are needed because prices are not available from markets.

The Research Client

The clientele of publicly supported research is society. In much of agricultural research, and other research areas, society is benefited by developing and encouraging the adoption of techniques or institutional arrangements which will increase the short-run profitability of the private operators. In the long run, society benefits as the gains pass through the market system. To the extent that the agricultural research sector is able to operate in this mode, it is most effective if it views private operators in the food system as its clientele and vice versa. Generally, this client relationship has existed in the agriculture.

Research on environmental regulation of the agricultural sector puts this client relationship in jeopardy. Rather than aiding the agricultural sector to serve society by producing more food more economically, the researcher is considering constraints on the sector aimed at improving the quality of the environment by reducing pollutants generated. At least in the short run, the operator perceives this as a reduction in flexibility or profitability. This role will often involve the researcher in conflicts between the agricultural sector and those who are adversely affected by pollutants generated. Depending upon the research results, the researcher may be appreciated by either of the groups but seldom by both. Thus the traditional client relationship is not likely to exist for the agricultural researcher working on agriculture's environmental problems. It also follows that in many cases the most productive research areas will be those where the sharpest conflicts exist.

Perhaps because of the acceptance of the existing client relationship, perhaps because the environmental thrust was generated outside agriculture and to a degree forced upon it, many in the research establishment do not seem to share the belief that the relationship between the agriculture research establishment and industry needs to be changed. Some, perhaps in an attempt to maintain the existing client relationship, would have the agricultural research enterprise attempt to thwart environmental policy initiatives. At the extreme, this perspective leads to a search for the negative aspects of environmental policy, rather than an evaluation of the total impact on society, both positive and negative. The question, "What are the costs of an environmental constraint?" is asked instead of, "Are the benefits greater than the costs?" A less dramatic reaction which will maintain the traditional client relationship is to determine the least-cost means industry can follow to comply with the environmental requirements. This is a viable and valuable role for the research establishment, but it leaves it outside the policy formulation process where a major contribution may be made. The more negative approach will involve the agricultural research establishment in the policy-making process but as a lobbyist. The more objective involvement suggested in the next section should be more productive.

Environmental Policy Research

It follows then that there are significant research needs in the policy-making process. In this discussion, I characterize policy making as a continuing process of assessment of conditions, identification of policy alternatives and analysis of their impacts, policy change, and a re-assessment of conditions. Research can play an important role in each phase. Since the policy-making process will make several iterations and may cycle continuously, the need for research is ongoing, which should provide some measure of comfort for researchers. At this point, I will attempt to indicate several of the research activities which may be pursued in relation to this process.

Analyzing Current Performance

Analyzing the performance of the economic-environmental system is one of the research roles in which agricultural economists may be involved. The initial identification of a possible or potential problem may be a research product, or the problems may be brought to the attention of the researcher as the result of a conflict between an agricultural group and a group affected by an agricultural pollutant. There are also, of course, cases in which the agricultural sector is adversely influenced by a pollutant from the urban or industrial sector. In any case, when a problem area has been identified, it is necessary to determine whether the performance of the system is acceptable or if it could be improved by intervention of the

public sector. The paucity of data and the newness of the phenomenon make some of these efforts quite challenging. Often it will be appropriate for the economist to team with individuals from other disciplines in order to deal adequately with the research problems faced. I will return to the topic of interdisciplinary research, but will observe here that attempting to piece together results from numerous separate single-discipline-oriented studies is not likely to be a satisfactory alternative. For example, the physical scientists may produce results at the extremes of a production function and not in the relevant range. Finally, this performance analysis research task may become a continuing monitoring and assessment process regardless of whether policy is enacted. If the policy has been enacted, it becomes a policy assessment activity.

Identifying Policy Alternatives

If, or when, the level of performance of the environment-economic system is not satisfactory, the policy formulation or reformulation process becomes a viable activity for the research community. This identification of policy alternatives is the second major research activity. The basic policy approaches to be used in the development of alternatives are education or persuasion, economic incentives (taxes or subsidies), regulations, and direct investments. Given the thrust of this conference, it is worth noting that all of these alternatives involve some form of regulation in a broader context. Even the education policy will establish a requirement that the individuals conducting the program perform in a certain manner. It is also worth noting here that the participation or compliance rate will not necessarily be higher with a mandatory rather than a voluntary policy. Anyone who has studied the policies developed in the environmental area will realize that they are often complex combinations of several or even all of these four basic approaches. Further, within each of these approaches there are numerous alternatives which will have greatly different impacts on the economic system and on the success of the policy in meeting the environmental goals. As an aside, a simple recommendation by an economist such as that a tax approach is preferable to regulation may not be considered fully because details on how it could be implemented are not provided. In some cases, the development of a policy approach not previously considered in the public arena may be an extremely valuable contribution to the development of efficient, effective policy.

Potential Performance of Alternatives

Given that alternative policies have been developed and specified in some detail, the research community can make its major contribution in the third area: comprehensive analysis of the potential performance of these alternatives. The research community can be expected to bring together the analytical tools and the, at least relatively, unbiased perspective necessary to assess accurately and credibly the impacts of the various policies. As economists we will automatically begin by assessing the relative costs and benefits of each alternative. Making this assessment is often complicated by the difference in data availability. Often it will be possible to develop rather detailed estimates with a reasonable degree of confidence on the costs of some of the policies. This is especially true when the cost impacts occur in the production and food processing sector. Estimating the benefits of reducing damages is much more difficult due to the lack of physical and market data on damages. Some progress, of course, has been made in this area by both economists and physical scientists but additional work is needed. Because of the difficulty of the research task, this area will remain important for some time.

Researching Various Policy Combinations

In order to conduct an adequate analysis of costs and benefits it usually will be necessary to consider the impacts of the several policy alternatives at various levels of aggregation. In addition to considering the local, state, national, and perhaps international dimensions of the problem, it often will be appropriate to consider the impact on regions that are not defined by political boundaries. An obvious example is a watershed.

The need for analyses at several levels of aggregation can be appreciated by considering several examples. In an analysis of the local impacts of an environmentally-oriented restriction the researcher will be able to include considerable detail on farm characteristics and production technique responses. However, it

will not be possible to estimate aggregate price or production impacts. In a national model the opposite will be the case, and both are necessary to understand the full impacts of each policy alternative adequately. It is not possible to determine the price impacts from a local model or the detailed production responses from a national model. Recognizing these limitations will help avoid drawing unwarranted conclusions from either model. The pervasive nature of most environmental problems means that the policy response is likely to be at the national level. This, of course, makes a nationally-oriented analysis of the several policy alternatives a high priority research activity. However, it does not eliminate the value of an analysis of the local impacts. A policy that has positive impacts at the national level but imposes severe burdens on individuals in certain areas will generate strong opposition from individuals in the affected areas. The political process would opt for an alternative that generated somewhat lower national benefits but avoided the severe local burdens, if the alternative existed.

In some cases, the regional analysis of policy alternatives will need to be supplemented by an analysis of the impacts on appropriate producing or receiving groups. When positive or negative impacts are concentrated on a small number of economic groups, these groups can reasonably expect that an analysis of policy alternatives will include special reference to their situation. Further, such groups can be expected to ensure such consideration by politicians, if not researchers, through lobbying efforts.

Long-Run Impacts

In the analysis of the impacts of the policy alternatives, the long-run impacts will need to be addressed. This becomes a special topic of concern here because many environmentalists do not discount the future. They imply a zero discount rate and may reject both the market and the lower social discount rates. Any analysis should reflect the fact that private firms will discount at the market rate of interest, and it is appropriate to include analyses of the social impacts at a range of discount rates. Conducting such analyses will allow the researcher to recognize the importance placed on the future by those who do not feel it is appropriate to discount the future and will provide a means of assessing the cost of policy options selected under such value systems. As an aside, it is my belief that economists need to continue to spend considerable effort attempting to define the appropriate discount rate(s) for use in the formulation of public policy. Relying solely on the inflated market rate is not acceptable to me. Possibly we should develop a range of discount rates for use in various classes of policy decisions. The time dimension of policy analysis is, of course, most important in those cases where the problem may become cumulatively more severe over time.

Equitability of Policy Alternatives

The final area of impact research that I feel needs significantly more attention is the equitability of the several policy alternatives. Often consideration of the equity aspects is omitted from or is a minor part of the overall analysis of the expected performance of alternative policies. This may explain some of the instances where the economist's input is not seriously regarded in the political arena. When several policy alternatives have roughly similar efficiency consequences, the equity aspects are likely to weigh heavily in the choice among them.

An equity analysis must include an assessment of the impact of the several policies on income and wealth distribution of those affected by the policy. However, the analysis of equity need not, and in my opinion, should not be limited to an equality-based equity criterion. Other criteria also are used in policy evaluation. If we could develop a systematic means of dealing with these criteria, the economist's contribution to the evaluation of policy would be enhanced. I am attempting to develop such an approach. One of the additional equity criteria I am considering reflects a commonly held belief that all in society should share in the cost of achieving social objectives. Farmers certainly believe that the cost of soil erosion control for the purpose of achieving water quality goals should be shared by all. The apparent general belief that all should participate in any energy conservation policy is another example. I am also working with a criterion which reflects the attitude that individuals should be rewarded, either positively or negatively, according to their contributions. The principle that the polluter should pay exemplifies this criteria. The at-

titude of many concerning the appropriate levels of environmental protection for future generations can also be viewed as an equity criterion. To the extent that such equity criteria are viewed as legitimate in the policy-making process, an equity analysis must address these criteria if the analysis is to be useful to the policy maker.

Given that the researcher or research team has conducted an analysis of the impacts of the several policy alternatives, he or she is, of course, in a position to make recommendations on the relative desirability of the several policy alternatives. Whether such recommendations are made will depend on the researcher's perception of the appropriateness of this activity. Clearly, debate on whether the researcher should enter the policy arena will continue and just as clearly, some will make detailed policy recommendations, and do so in a very visible manner, while others will carefully refrain from making any recommendation.

With or without the recommendation of the researcher, and almost always before a full analysis is accomplished, the political process will result in a policy change. The adoption of a new policy opens another research area. The research community can concentrate effort on the policy that has been adopted and conduct much more detailed analysis than was reasonable when the several alternatives were being considered. In addition to providing additional details on impacts, research can be conducted on the appropriate responses to the new policy. Determining how industry can comply effectively and efficiently with the new policy would lend itself extremely well to the agricultural research enterprise. It is analogous to analyzing industry response to any other technical or institutional change. This may include the analysis of alternative technologies and the managerial actions necessary to implement such technologies. While this type of research is, as indicated above, inadequate as a total response to the problem area, it may be a very important research area.

Analyzing Institutions

A somewhat similar avenue of research, but one in which we have much less experience, involves the development of institutional arrangements for efficient implementation of the policy which has been adopted. Ideally much of this detail would have been included in the initial specification of policy alternatives. It is my impression that the development of institutional arrangements under which policies are adopted may be a very important factor in determining the economic impact of that policy. Often it is in this phase of the development of an overall policy that the choice between performance and technique standards is made.

If economists believe that technique-based standards can stifle innovation, they need to conduct research and make input on this choice in order to counter the general preference of lawyers and "bureaucrats" for more easily enforceable technique standards. Often the guidelines are developed by state or federal bureaucracies through an iterative procedure that includes seeking expert advice and public comment on several drafts of guidelines for policy implementation. Since industry input tends to be discounted as biased, the research community may be able to make a significant impact on the guidelines adopted. However, because of the short time periods available, it is difficult to secure resources to support an analysis or even to formulate a comprehensive set of recommendations. When these problems are considered in combination with the often mundane nature of the task, it seems likely that we will continue to do less in this area than might be warranted. While building recognition of this activity into the reward structure may help, I doubt that it will bring forth adequate effort.

Assessing Policy Performance

The final major area of research—policy performance assessment—may begin as experience accumulates under the new policy. Research conducted will be of the same nature as the assessment prior to policy adoption. Clearly, policies should include provisions for accumulating data on performance although they often do not. The cumulative nature of the pollution problem requires research on the cumulative impacts of policies for environmental objectives, just as we need analyses of the cumulative costs of regulation.

It is my expectation that, while there occasionally will be rather drastic changes in public policy, more commonly rather minor adjustments will be made on an incremental basis. Thus, the assessment of policy performance, the development of policy alternatives, the assessment of their impacts, the development of

efficient means of implementing policy, and the renewed assessment of policy performance will be a continuing process. In part, this is a continuing process because neither the research enterprise nor the policy-making process operate with sufficient precision to specify an optimal policy. In addition, because there are constant changes in the economic and the natural systems, the policy-making process is aimed at a moving target.

Other Research Needs

In any research area there is a continuing opportunity to improve the quality of the research through the development of improved research techniques. For example, we probably will find increased use of systems analysis techniques as they are adapted to the problems we face. As noted above, the need for improved techniques in the measurement of the benefits associated with the reduction in pollutant levels is an area that has begun to receive some needed attention.

My experience indicates that attempting to develop the cost of institutional arrangements necessary to implement policies is a nearly uncharted area. If the public sector is to continue to be active in the environmental area, the challenge of developing efficient institutions to implement these policies will continue to be important. As in several other areas, an interdisciplinary team of researchers is probably needed to deal effectively with this problem.

A somewhat analogous need is to make the research enterprise more efficient. Conducting a comprehensive analysis of a significant question is preferable to aggregating the results of several less ambitious research efforts. However, because the research task is extremely large and complex, it is often necessary to utilize the aggregation approach. Thus we need to know how to do it, and the resources needed must be allocated to get the job done. We also need to consider the nature of the research enterprise itself, the allocation of resources and rewards, to determine whether it is possible to generate a system better able to deal with the large and complex problems found in the environmental area. Here again the team approach may be a part of the answer.

On several occasions I have referred to, or implied, that there is a need to work with individuals from other disciplines. It is apparent that environmental policies are not formulated on the basis of the recommendations of economists alone. Further, not all of the expertise needed is likely to reside in the agricultural establishment. Severe problems can be expected if we attempt to conduct research in areas outside our training. If the research on alternative policies is conducted in an interdisciplinary mode, we force the integration of information from the several disciplines. If operating an interdisciplinary team is to be more than time-consuming and frustrating, this team will need to develop a research plan. Simply dividing a large grant among several researchers who conduct independent subprojects and then attempt to integrate their findings will very seldom produce the real integration needed. But it may be better than no integration at all. Under the alternative of separate analyses by disciplinary specialists, the politician must select from among the analyses conducted by the economist, political scientist, sociologist, engineer, ecologist, lawyer, and other in order to determine the desired policy alternative.

Summary

Environmental regulation is here to stay. Because the physical and economic phenomena involved are complex and not adequately understood, a research response is needed. Because there is an area of conflict between people in the agriculture community and some of those advocating environmental regulation, our involvement will require a new client relationship which likely will be somewhat uncomfortable to some. Our major research tasks can be best seen in relation to the policy formulation process. We need to consider involvement in the identification and measurement of problems, the development of alternative policies, the analysis of these alternatives, the development of efficient responses to policy initiatives, and the assessment of policy performance.

In addition, we need to seek improved research techniques and attempt to improve the operation of the research enterprise. One of the major changes needed may be the utilization of interdisciplinary research teams rather than relying on the aggregation of results from separate, smaller research activities.

Agricultural Workplace Safety: A Perspective on Research Needs

Stan G. Daberkow and Conrad F. Fritsch

"Safety is a scarce resource. To allocate this resource optimally, two basic questions must be answered. What level of safety shoud we be seeking? (How safe should we be?) What is the least costly way of achieving this level? (In what ways can we buy safety most cheaply?)" (Lave 1968, p. 512).

These two questions are simple and direct, but, unfortunately, answers to them have proven elusive. Response to the first is contingent on understanding the costs and benefits associated with each attainable level of workplace safety. Answers to the second are obtained by evaluating alternative technologies and public policy options.

In recent years, safety standards have been the most frequently advocated method for reducing the level of workplace injuries, illnesses and deaths. Billions of dollars have been expended and thousands of new regulations have been written. In the agricultural sector alone, estimates prepared prior to promulgation of the roll-over protection standards for tractors and the farm machinery guarding standards suggested that first year costs of these combined standards equaled about 20% of the total annual agricultural wage bill (U.S. Department of Labor 1974).

The regulatory approach, as embodied in the Occupational Safety and Health Act of 1970 is but one of five possible approaches to address the goals of workplace accident reduction. The others include: (*a*) the competitive market approach (i.e. setting wage differentials to compensate workers for higher levels of risk); (*b*) resorting to the judicial process for assignment of fault and awarding of compensatory judgments; (*c*) allocating the risk and compensatory payments through the insurance industry; and (*d*) the use of educational and informational institutions to distribute results of safety research efforts to workers, employers and self-employed entrepreneurs.

It is the opinion of the authors that an optimal solution to the two questions posed at the beginning of this paper will come about only as a result of an integration of these five approaches. To foster discussion of this desired goal the present paper is designed to: (*a*) provide a cursory examination of workplace accident causal factors; (*b*) define the nature of each policy alternative which impacts on the level of workplace safety; (*c*) describe the application of each policy to the agricultural sector; and (*d*) identify the research required to move in the direction of providing policy responses to the twin questions of "how much" and "at what cost?"

Accident Causal Factors

Accident causation typically is discussed in terms of two factors: improper employee behavior, including a negligent fellow worker, and a hazardous work environment. Under this view, workplace accident and disease are jointly produced by the work environment and worker behavior (on and off the job). For example, a National Safety Council study (quoted by Keefer) showed that 18% of all accidents were caused by environmental factors; 19% were due wholly to behavioral factors; and 63% were a combination of these factors.

A review of accident data by industry exposes several empirical regularities over time. While industrial injury rates have varied among industries with some rising (e.g. meat packing) and some declining (e.g. logging, highway construction) the ranking of industries, by injury rate, has shown remarkable stability over time. An industry with a relatively high injury rate in 1940 will tend to have a high rate in 1970. An obvious variation in injury rate exists across industries (e.g. refuse

---

Stan G. Daberkow is an agricultural economist, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture and Conrad F. Fritsch is senior economist, Minimum Wage Study Commission, Washington, D.C. The views expressed in this paper are solely those of the authors.

The authors wish to express appreciation to R. Adams, D. Fisher, W. Glasier, E. Jesse, and R. Phister for comments on earlier drafts.

collection has an injury rate of 63.9/million man-hours while banking incurs 2.4 injuries/ million man-hours). Table 1 gives the most recent injury rates by highly aggregated industry classes.

Another empirical regularity found in industrial injury statistics relates to firm size. Table 1 indicates this association for several selected industries. The majority of industries tend to follow an inverted u-shaped curve when injury rate is plotted against firm size. Possible reasons for lower injury rates among the very large and small firms may be related to labor market factors. Large establishments have lower labor turnover rates, hire fewer young workers, have a small proportion of workers which are production rather than office or clerical oriented, or employ more safety personnel or resources. On the other hand, smaller firms supposedly enjoy closer employee-employer relationships, making safety a personal factor.

The incidence rate for agriculture does not follow the trend of other industries. Agriculture's incidence rate increases as size increases. In the one to nineteen employee category, agricultural firms have only the fourth highest incidence rate, while firms in the 1,000 to 2,499 employee class have the highest incidence rate for all industries listed.

Using the standard errors published by the Bureau of Labor Statistics (BLS) one can detect statistically significant differences between industries. At the 95% confidence level (assuming a normal distribution and that all the variation arises from sampling error) contract construction, manufacturing and mining have significantly higher incidence rates than agriculture while wholesale and retail trade, and transportation and public utilities are not significantly different from agriculture.

The accident rate (on and off job premises) is also associated with the age and sex of workers. The age group 20–24 has twice the injury rate of all other workers. However, the total injury rate masks another phenomenon. Younger male workers are more likely to be injured but less likely to be killed. Conversely, males over 50 are less likely to have accidents but when they do, they are more likely to die. Furthermore, males are three times more likely to be injured than females. Oi (1974) suggests that sex/age differentials in work injury rates may be proxy variables for other causal factors such as innate accident liability (accident proneness), perceived costs of work injuries, attitudes toward risk bearing, occupational and industrial affiliation, and job experience.

Labor turnover and job experience have also exhibited a strong association with injury rates. Preliminary evidence indicates that injury rates for less than one month on the job are two-and-one-half times higher than after six months on the job. Obviously, lack of familiarity with one's tasks could account for this relation. Age and experience are highly correlated, providing an explanation of lower injury rates of older workers by their cumulative work experience. Seasonal workers are an obvious example of workers with a high turnover and little job experience. Agricultural workers certainly fit in this category as do those in the logging and food processing industries.

Alternative Approaches to Workplace Safety

Market Approach to Workplace Safety

Use of a competitive labor market model to illustrate the economics of safety dates back to Adam Smith, who was the first to assert that individuals could be induced to take risky jobs only by offering a risk premium. More recent analysis can be found in the formal models of Oi (1973, 1974), Smith (1973, 1974, 1976), Gregory and Gisser, and Russell.[1]

Workers employed in higher risk occupations or industries supposedly *ceteris paribus*, receive higher wages (a risk premium) over their fellow workers engaged in less hazardous tasks.[2] The relevancy of this risk premium

[1] Most of these models are neo-classical firm optimization models where profits are maximized or costs minimized subject to the appropriate constraints. Oi (1973), however, views injuries as inherent in the production process and treats this topic in a joint product framework where injuries are a by-product with no market. As such, injuries are viewed as externalities and treated in the same manner as environmental problems. The similarity of standards setting in this discussion with those in the environmental field can be ascertained in Baumol and Oates (1975, p. 140–144). A distinction between workplace and environmental side-effects of externalities can be made conveniently on the basis of the participating parties. Workplace side-effects are confined to the parties making the transaction whereas environmental side-effects impose costs (or benefits) on a large number of people who were not parties to the transaction.

[2] Smith (1974) did conclude that employers in the manufacturing sector have responded to incentives to provide workplace safety. He found that in manufacturing industries where the yearly death rate is 16/100,000 workers, employees receive approximately 1.5% higher wages per year on the average than do employees with comparable skills in manufacturing industries which have an average rate of 8 deaths per 100,000 workers. However, many hazardous jobs do not pay well and they are often held by nonunion, unskilled, minority groups with limited options. Obviously factors other than "risk" influence wage levels.

Table 1. Occupational Injury Incidence Rates, Private Sector, by Employment Size and Industry Division, United States, 1974 and 1975

Number of Employees	Private Sector 1974	Private Sector 1975	Agriculture, Forestry and Fisheries 1974	Agriculture, Forestry and Fisheries 1975	Mining 1974	Mining 1975	Contact Construction 1974	Contact Construction 1975	Manufacturing 1974	Manufacturing 1975	Transportation and Public Utilities 1974	Transportation and Public Utilities 1975	Wholesale and Retail Trade 1974	Wholesale and Retail Trade 1975	Finance Insurance Real Estate 1974	Finance Insurance Real Estate 1975	Service 1974	Service 1975
	Incidence Rates per 100 Full-Time Workers[a]																	
1 to 19	5.4	4.3	6.3	4.7	8.7	9.6	13.4	10.4	11.0	9.0	7.0	6.5	4.4	3.6	1.8	1.4	2.6	2.0
20 to 49	9.5	8.4	10.3	9.2	12.8	12.0	19.1	16.8	15.2	13.9	12.1	10.1	8.6	7.4	2.1	1.8	3.9	3.7
50 to 99	12.3	11.2	13.9	11.4	11.9	14.9	21.8	20.1	18.1	16.1	13.3	11.6	10.9	10.0	2.6	2.6	6.1	5.9
100 to 249	13.7	12.2	13.8	13.1	11.2	12.2	23.2	20.9	18.5	16.7	11.8	9.6	11.8	10.6	3.0	3.1	7.7	7.4
240 to 499	12.9	11.4	13.5	14.6	9.2	10.2	20.3	19.0	16.4	14.2	9.3	8.8	11.6	10.8	2.8	2.7	8.4	7.3
500 to 999	11.2	10.0	19.6	13.2	6.8	7.4	18.3	16.2	13.1	11.7	9.8	9.4	11.0	10.5	2.6	2.4	8.5	8.0
1,000 to 2,499	9.8	8.7	25.1	28.8	5.3	4.6	17.3	14.2	11.0	9.5	8.9	8.8	10.6	10.6	2.5	2.1	7.8	7.3
2,500 and over	8.4	7.3	—	—	6.0	2.7	4.7	5.9	9.0	7.6	9.1	8.9	9.9	6.7	1.9	1.9	5.9	5.6

Source: U.S. Department of Labor, 1977.
Notes: Dashes indicate no data reported. Data refer to Wage and Salary workers only.
[a] The incidence rated represent the number of injuries per 100 full-time workers, and were calculated as: (N/EH) × 200,000, where N—number of injuries
EH—total hours worked by all employees during the calendar year
200,000—base for 100 full-time workers (working 40 hours per week, 50 weeks per year).

market model is linked to four key assumptions: (*a*) available information and employee understanding of risks associated with each job opportunity; (*b*) mobility of workers; (*c*) employer's perception that benefits are received from supplying job safety and health; and (*d*) the existence of risk premiums.[3] The optimal level of safety may not be attained when one or more of these assumptions are violated. If workers are ignorant of risks associated with their job they may incorrectly assess the value of their risk premium. Thus, employees' underestimating the risk (or correctly estimating the risk, but having no alternative employment) will allow employers to pay a lower wage which will not adequately compensate an employee for the risk. Employers are assumed to recognize the profitability of making safety investments.

The assumptions regarding full understanding by workers of workplace hazards, risk premiums, and free mobility of workers between occupations and industries are rarely realistic in practice. Indeed, many current labor market institutions including unionization, minimum wage guarantees, internal firm wage bargaining procedures, passage of Worker's Compensation laws, and the improvement of voluntary workplace health and safety programs suggest that, as a society, we have opted to provide workers with basic guarantees against the vagaries of free market labor allocation processes.

Judicial System

Tort law (i.e. a wrongful act, injury or damage for which civil action can be brought) is one mechanism whereby an injured employee can recover costs incurred by him due to the employer's negligence. For agriculture, tort law is one method of encouraging farm safety on the part of both the farm employer and farm worker especially in states where agricultural workers are exempt from coverage under Worker's Compensation laws.

The tort law approach to setting the level of safety relies on the court's ability to identify the negligent party *ex post*. However, the judicial system can still encourage optimal behavior from both the employee and employer viewpoint (Kasper). Theoretically, the court system can allocate the accident costs in such a way that the sum of accident costs and accident prevention costs would be minimized. To accomplish this goal, fault would be assigned to the party which could have avoided the accident at least cost.

The legal system has not fulfilled the ideal successfully. For example, in the case of workplace safety, an employer may invoke three common-law defenses: "(1) contributory negligence on the part of the employee himself; (2) contributory negligence on the part of another employee (fellow servant rule) and (3) assumption by the employee of the risk that led to the injury in question when he took the job" (Fisher, p. 12). Furthermore, the causal link between the work environment and an employee's health status can be very tenuous, resulting in inappropriate incentives for the provision of safety. In light of the difficulties associated with identifying chemical-related maladies it is understandable that cases of machine failure are more likely to bring compensation for injury than is the misuse of a chemical. The expense in time and money of operating the legal system can be extensive. One does not receive compensation for time spent in litigation; no interest accrues to the awards for the time delay between the accident and the liability judgment; and court costs and legal representation can consume a major part of the compensation even before the case is tried. An employer (or his insurer) is often in a position to negotiate liability suits more effectively than is the employee. The uncertainty of outcome plus the large variation in settlements and awards for similar incidents also limit the incentives for the provision of optimal safety levels (Cornell, Noll and Weingast). The cumulative effect of these factors is that employers do not have reliable information on which to allocate safety resources.

Another aspect of tort law, which is more applicable in the case of the self-employed farmer, is product liability. The general area of product liability is currently in a legal turmoil. A study by the Department of Commerce Interagency Task Force on Product Liability has found that some industries are experiencing an increase in litigation because of liability imposed on them for injuries caused by their

[3] This model minimizes the sum of accident costs and accident prevention costs. Minimizing one or the other leads to a misallocation of resources as Lave points out (1971, p. 101). For instance, since over half of all accidental farm fatalities occur to persons over 45 years of age, society could cut farm deaths in half by requiring all farmers to be less than 45 years of age. This step surely would reduce deaths, but it is not consistent with maximum societal welfare. When the cost of preventing an accident or illness is greater than the accident costs, welfare is maximized when the prevention costs are not incurred and the accident is allowed to occur.

products. In the case of defective farm equipment, which has caused an injury to either the farmer or his employee, the injured party has recourse through the judicial system. This assumes of course that the injured party meets certain due care standards (Diamond).

Traditionally, farmers as a group, have not articulated a strong desire to improve the safety features of farm equipment. However, representatives of the Farm Implement and Equipment Institute have indicated to the authors that the increased likelihood of product liability suits arising from injuries and deaths associated with the operation of farm machinery has become a major concern of farm equipment manufacturers in recent years. In spite of that, no systematic data are available on the number of liability suits filed by producers against input suppliers on the basis of injury or disease.

Insurance System

Insurance is another mechanism to encourage the optimal level of safety for both the employee and employer. Assuming both have insurance against damages (protection from liability damages in the case of the employer and health costs, rehabilitation costs and loss of income in the case of the employee) their premiums are theoretically based on the probability of an adverse event.[4] Therefore, employees and employers have direct pecuniary incentives to keep expected losses as low as possible.

Nevertheless, insurance has its drawbacks. Accurate estimation of the probability of loss is necessary to establish premiums, which in turn inspire insurance owners to behave so as to minimize their insurance costs. In current practice, premiums are not set on an individual or firm basis, but on a group basis, thereby blunting the incentive mechanism. (However, firms known to be poor risks can be placed in an assigned risk pool.) This problem is really a manifestation of the insurance carrier's inability to estimate the probability of an event occurring to any one individual.

A special case of insurance which was partly designed to influence workplace safety is the system of Federal/State Worker's Compensation law (Rosenblum). This program, administered by individual states, basically provides for compulsory no-fault insurance. In a number of states, an employer is required to buy liability insurance (or to self-insure under certain conditions). In the remaining states, the employer can voluntarily subscribe to Worker's Compensation insurance. These laws obligate the insurer to compensate the employee for lost income, and medical and rehabilitation costs deriving from a job-related injury regardless of who was at fault. In return for fixed schedules of benefit payments for a job-related injury, the employee's recourse to further legal action is limited.

Several arguments were proffered for the establishment of Worker's Compensation, most of which attack the assumption of the market model presented earlier. Perfect perception of workplace hazards and perfectly competitive labor market operations were assumptions thought to be unrealistic in practice. It was argued that workers would "prefer current consumption over protection and will demand the risk premium in cash" (Rosenblum, p. 230). Furthermore, by linking premium costs to the firm's accident experience, Worker's Compensation was designed to provide employers with incentives to prevent accidents.

Although assigning premiums to employers in an inverse relationship to accident occurrences is theoretically enticing, actual rate setting procedures are complex, vary by state, and may have little impact on the workplace environment. Under current procedures each state (or private carrier) anticipates the total loss (i.e. benefits to employees injured on the job) resulting from industrial or occupational accidents (Fisher). Losses are calculated as a function of the frequency and severity (dollar amount) of claims. In turn, the number and severity of claims is a function of the inherent hazards in the industry as well as the interpretation of the statutes and the level of the awards allowed by the state institutions involved. The rate calculation procedure is then subject to an additional adjustment called experience rating, which takes into account the individual employer's recent accident record as measured by benefits paid out to employees. In most states, firms having premiums in excess of $750 per year (generally firms with four or more workers) are experience rated. It is estimated that only about 30% of all employers meet this criterion.

[4] If the worker is uninsured, in regard to on-the-job health, rehabilitation, and/or loss of income insurance, he may shift these costs onto the taxpayer via welfare payments. Social Security supplements are also available to families whose breadwinner is permanently, partially, or fully disabled because of on-(or off-) job accidents.

Since Worker's Compensation premiums should have an inverse relationship with the number of workplace accidents, it can be expected that states with high benefit levels should have lower injury rates than low benefit states. Chelius (1974) did not find this relationship to hold. Russell and Smith (1976) also pointed out that the premium-setting mechanism for Workman's Compensation does not encourage optimal safety levels.[5]

Legislatively Mandated Workplace Standards

If the market model produces less safety than consumers or workers are willing to pay for (in either higher product prices or lower wages, respectively), and the litigation and insurance options are deemed inefficient or ineffective approaches, then at least one rationale (i.e. market failure) for government intervention exists. The assumption underlying regulatory action is that those standards promulgated and enforced by the agency have a "significant" effect on reducing workplace injuries and disease (Oi, 1973). However, two practical issues about these government regulations immediately arise: (*a*) costs and returns of safety standards will vary by firm since rules which are the same for each firm are unlikely to be optimal for each firm and (*b*) it will be unlikely that a government employee enforcing these standards will be aware of the least-cost technology available to each firm (Chelius, 1973).

The Occupational Safety and Health Act of 1970 created the most comprehensive workplace standard setting institution at the federal level. The key provisions of the Act are as follows:

1) General Duty Clause (sec. 5(a)(1)): Each employer shall furnish to each of his employees, employment and a place of employment which are free from recognized hazards that are causing or likely to cause death or serious physical harm to his employees.
2) General and Specific Standards (sec. 5(a)(2)): Each employer shall comply with occupational safety and health standards promulgated (by the Secretary of Labor) under this chapter.
3) Employee's Duties (sec. 5(b)): Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this chapter which are applicable to his own actions and conduct (Miller, p. 615).

The first two provisions apply to the employer and, if he is found in violation of either, the Act provides for fines and penalties or even plant closure if there is imminent danger of death or serious physical harm. The third provision applies to employees but the Act contains no penalty for violation of this provision.

There seems to be some consensus, at least among economists, that economic efficiency was not part of the Occupational Safety and Health Administration's (OSHA) initial criteria in evaluating standards. The approach taken by OSHA administrators at the time the agency was formed, a legitimate one in view of the congressional mandate, is that absolute protection or zero-risk was to be attained in the workplace (Oi, 1975 and Smith, 1976). The attainment of these goals (as interpreted by various court rulings) could be constrained only by the reduction of risks to the technologically feasible minimum or "that protection which can only be achieved by ceasing production" (Oi, 1975, p. 2).

The current approach to workplace standards setting at OSHA has the following hierarchy: (*a*) engineering design; (*b*) administrative procedures (i.e. forbidding certain employee work practices or behavior); and (*c*) personal protective gear. Generally, reducing accidents through the engineering design is much more capital intensive and costly whereas personal protective gear, while less costly, may impair worker productivity or increase worker discomfort. From an efficiency or cost-effective point of view, a sumultaneous rather than hierarchial analysis of the three options is necessary.

Economic considerations have taken on greater significance in recent years. Under executive orders in effect since 1975, inflationary impact statements or regulatory analyses must be prepared to estimate the costs of implementing any proposed federal regulation. Regulations expected to cost more than $100 million in one year are subject to a more comprehensive inflationary impact analysis. Although this method provides a crude measure

---

[5] Workman's Compensation premiums can also be viewed in the broader context of a percentage of the total payroll. This percentage varies over time, industries and states. Between 1940 and 1970, this percentage for all industries and states has varied between 0.89 and 1.19 (Rosenbloom, p. 179). In manufacturing, in 1969, the average percentage was 1–2%; nonmanufacturing was 0.5% with a range of 0.1% for insurance companies to 1.8% for primary metals. State variations in 1971 were from .67% in Utah to 3.12% in Arizona. Although, the total dollar amount of premiums is significant, (almost $5 billion in 1970) the incentive for an individual firm to change its safety behavior is marginal since Worker's Compensation premiums are only a very small and relatively constant level of total payroll.

of economic costs, no attempt is made to estimate the value of benefits received.

In addition to regulations which are ineffective (rules with no impact on injury rate) and cost inefficient (hazards which can be eliminated with techniques less costly than those required by law) several other difficulties beset regulatory agencies. Extremely complex or stringent rules are likely to lead to noncompliance by firms, as are rules which lack enforcement by inspectors. Detailed standards for each occupation within each industry are impossible. However, standards applicable at the industry level lack specificity. Controversial standards (i.e. those eliciting strong pressures from opposing interest groups) become difficult to change or adopt. Constant changes in technology and materials create constant need for new or different standards.

Safety in Agriculture

Agricultural production firms are noted for their diversity including variations by region, farm type, production processes, and size of farm (acres, sales, or number of employees). However, some unique characteristics of farm firms and their implications for safety can be identified. Most farm operators and employees perform a wide variety of tasks (i.e. heavy equipment operator, construction work, chemical applicator, mechanic). Very little farm work is of the assembly line type nor is it of a repetitive nature. Length and intensity of farm work days also exhibit high variation. The number of hours per day devoted to planting, harvest, certain livestock operations and various other activities are often dictated by weather conditions. In addition, many agricultural activities require transitory work sites as opposed to permanent surroundings. Nonadjoining fields require mobile farm equipment which may traverse variable types of terrain. An increase in part-time farmers leads to added unfamiliarity with job tasks as well as fatigue from a second job.

The 2.7 million persons aged 14 and over who did some hired farm work in 1977 had several interesting characteristics: (*a*) 55% of hired farm workers were under 25 years of age; 28% were 14–17 years old; (*b*) 77% were male; (*c*) 50% were not in the labor force most of the year (the majority of these were students); (*d*) 39% worked on farms less than 24 days (casual workers) and 36% worked between 25 and 149 days (seasonal labor); (*e*) 41% had non-farm jobs at some time during the year (Rowe).[6]

As noted earlier, empirical consistencies exist between worker characteristics and injury rates. Age, sex, and work experience were among the significant variables related to differing probabilities of accident occurrence. The relatively young age of the hired farm workers plus the preponderance of males would lead one to conclude, *ceteris paribus*, that farm workers would have a relatively high injury rate. Combined with the fact that many farm workers are part-time, one would suspect that labor turnover is high and work experience low. In fact, of the 700,000 farms hiring workers in 1974, about two-thirds hired workers for fewer than 150 days per year (U.S. Department of Commerce, 1974).

These factors, the farm workplace environment and the hired work force provide a general explanation for the relatively high workplace injury rates recorded for the agricultural sector. Of course, variation by farm type, region, etc. modifies these generalities.

The Judicial System

"Farmers sentiment about the need for safer machinery has never been intense, and the generally conservative farm community has failed to produce even the vocal minority characteristic of users of other products" (Kurdle, 1975, p. 69).

The above quotation may explain the nonlitigious nature of farm operators and farm workers. From a farm-operator perspective, the court system might provide a mechanism to increase workplace safety via product liability related to farm equipment.[7] From an employees' view, the tort system is often the only recourse in the case of the employer's workplace negligence, unless the worker is covered under Worker's Compensation laws. In reality, not everyone has equal access to legal mechanisms. Farm workers would not appear to have the resources to claim access, at least not in relation to the employer or farm operator. This is especially true in view of the

---

[6] The farm worker survey is restricted to farm workers who are residents in the United States during the December survey week.

[7] 'Since farmers are in the business of "manufacturing" food, are they liable for damages caused by "dangerous" food products consumed by the public? Chemical residues (i.e. stilbestral, herbicides, pesticides, nitrates) would appear to be the biggest problem. Could farmers force this liability back to chemical manufactures? Does inspection of agricultural products by a government agency relieve farmers of product liability?

employer's three common law defenses noted earlier.

The Insurance System

A large number of farm operators and most farm employees apparently employ a combined strategy of self-insurance, market insurance and self-protection when dealing with workplace hazards (Ehrlich and Becker). Obviously, the more time or money spent on self-protection (i.e. workplace behavior) the less will be spent on market and self-insurance. This strategy is complementary to coverage under the Social Security system, which provides for benefits payments in case of permanent partial or full disability, regardless of whether the injury was occupation related or not.

Some states require farm employers to purchase insurance coverage under Worker's Compensation laws while other states allow elective coverage by farmers (Schramm). In these states a farmer who qualifies for coverage and choses not to come into the Worker's Compensation system, loses his three common law defenses should he be sued for negligence. Thirteen states currently make no distinction between agricultural employees and other types of industrial employment and, except for New Jersey, these states have compulsory coverage laws (Daberkow and Fritsch). Another seven states cover farm workers except under some relatively minor circumstances. Four other states require coverage after a substantial payroll threshold ($15,000–$25,000) is reached. The remaining states exempt agricultural employees specifically or exempt a large number by allowing employers of three or fewer workers to come voluntarily under the Worker's Compensation insurance system. Therefore, an exact account of the number of farm workers actually covered by Worker's compensation is unknown, but the aggregate number of farm workers in the above 24 states accounts for over 55% of the total (U.S. Department of Agriculture, 1977).

The impact of experience rating on the safety record of farm employers who are required to purchase Worker's Compensation insurance is not available from secondary data sources. Experience rating of very small firms causes actuarial principles to be compromised. Insurance firms serving farms or other relatively small employers have little data (or incentive) to experience rate these firms (Lewis). However, firms with extremely poor safety records can be placed in assigned risk pools with premiums substantially above ordinary rates.

Even though over 50% of the U.S. hired work force is estimated to be covered by Worker's Compensation laws, one study indicates a lack of awareness by employees of available benefits. Howitt and Moore, using a primary survey of farm workers in California, found that nearly 70% of the farm workers sampled were unaware of Worker's Compensation laws. In addition, they found that premiums for farm firms did not change by claim history. Obviously, the incentives for cost internalization by the firm, through this institution, are rather weak.

Agricultural Workplace Safety Standards

Although various states may have additional workplace regulations or standards affecting farm workplace safety, the Occupational Safety and Health Administration currently enforces five specific regulations affecting agriculture. Agricultural production firms covered under these federal regulations are exempt if they do not hire more than ten employees. Present regulations in agriculture cover the following: (*a*) storage and handling of anhydrous ammonia; (*b*) temporary labor camps; (*c*) tractor roll over protection equipment (ROPS); (*d*) machine guarding; and (*e*) slow-moving vehicles. Re-entry standards for organophosphate pesticides have been recently rescinded and placed under the jurisdiction of the Environmental Protection Agency.

A brief look at OSHA's agricultural enforcement program will emphasize the limitations of this approach to reducing workplace accidents. In formal terms, the incentive for employers to comply with OSHA standards is a function of the probability of being inspected, the probability of an inspector detecting a violation, and the amount of the penalty imposed. OSHA reports inspection activity by industrial category and, therefore, agricultural statistics include firms in forestry and fisheries. The most current data (from 1974) indicates that there are fewer than 120,000 farms which hire ten or more employees during any part of the year (U.S. Department of Commerce, Bureau of the Census, 1977, Table 15, Part IV).

Table 2 isolates the three variables noted

Table 2. Selected OSHA Inspection Data for Agriculture, 1975 and 1976

Item	1975	1976
Total inspections	1,116	2,317
First time inspections	892	1,697
Citations	720	1,373
Total violations	3,282	6,325
Serious violations	31	45
Total penalty ($)	27,840	44,870
Total employees covered[a]	46,925	90,801
Share of firms inspected first time (%)	0.7	1.4
Number of citations per first-time inspection	0.81	0.81
Number of violations per citation	5.56	4.61
Share of serious violations (%)	0.9	0.7
Penalty per citation ($)[b]	38.70	32.68
Penalty per violation ($)	8.49	7.09
Penalty per employee ($)[c]	0.59	0.49

Source: OSHA Inspection Activity Data, 1975 and 1976 unpublished, Occupational Safety and Health Administration.
[a] Employees covered is somewhat misleading since follow-up and repeat inspections count the same employees a second time.
[b] Penalty paid per serious violation is not available.
[c] Based on the estimated number of farms with ten or more employees.

above. The probability of being inspected in 1975 and 1976 was 0.007 and 0.014 respectively.[8] Once the inspector had arrived, the probability of receiving a citation was 0.81 in 1975 and in 1976. Each inspected firm violated an average of four to six standards in either year, while the number of serious violations (life-threatening) was less than 1% of total violations. The average penalty per citation was $38.70 and $32.68 in 1975 and 1976, respectively, while the average penalty per violation was $8.49 and $7.09. The average penalty per employee was even more miniscule—$0.59 and $0.49 per employee in 1975 and 1976 respectively.

The above exercise suggests that even though the probability of receiving a citation once an inspector arrives is high, the probability of arrival and the average penalty levied is quite low. This translates into a very small *ex ante* incentive for the employer to comply with OSHA standards.

[8] This is an admittedly back-of-the-envelope estimate, since inspections are not entirely random. Accidents or employee complaints can trigger an Occupational Safety and Health Administration (OSHA) inspection. Furthermore this analysis does not include the probability of a state inspection in those states which have their own inspection system.

Safety Education Institutions

Several organizations ostensibly have improved the level of farm safety via their safety education programs. Such programs rely on voluntary compliance with suggested safety practices. Repeated warnings and educational safety notes are designed to keep farm operators constantly aware of farmstead hazards, thus lowering the risk of injury. The federal government's role in agricultural safety education has been primarily through the U.S. Department of Agriculture via the Extension Service. The Land-Grant University System has also contributed to this education effort. One notable nongovernment nonprofit agency associated with farm safety and safety in general is the National Safety Council (NSC). This group develops educational information and presents seminars for safety specialists employed with private industry and state Extension Services.

One can view the educational safety expenditures of the federal and state agencies as a safety information accumulation, synthesis, and distribution system. In this context, the agricultural industry's ability to secure safety information subsidized by the public sector seems somewhat unique. A number of economists have suggested that the "proper" role of government in the area of workplace safety should be restricted to safety research (analysis of risks) and information dispersal (Goldberg). Workers, employers and self-employed farmers thus are able to use the available information to determine their optimum level of safety consumption. Workers might respond by demanding risk premiums in their wages, seeking other employment, opting for greater self-protection through diligent work behavior or a combination of both. Employers and self-employed farmers are likewise induced to change their workplace environment or change their work habits.

Agricultural Safety Data

No discussion of safety is complete without a discussion of data problems. The 1970 Occupation Health and Safety Act included a provision to secure data on workplace injuries. The system was designed to ascertain accident causal factors as well as to determine accident injury rates across all industries over time and in a consistent manner. Published statistics include the number of workplace accidents,

injuries, illnesses and fatalities by two and three digit Standard Industrialization Code groups. Agricultural coverage is limited to workers employed on farms hiring ten or more workers.

The NSC annually releases data that purports to measure levels and rates of farm and farm work injuries and fatalities. These estimates are not developed using scientific sampling procedures and, hence, the reliability of the estimates is not known. In some cases, estimates appear to vary considerably from those developed by the Bureau of Labor Statistics (BLS), but population differences preclude direct comparison with BLS statistics.

The NSC, in cooperation with the state Extension Services, also collects comprehensive state accident data on a recurring basis. States are requested to participate at five year intervals. The purpose of the surveys is to identify the type of accident and its severity, determine the characteristics of the victim and describe the factors associated with the occurrence. These surveys provide a large mass of data but weak sampling designs limit their usefulness. The absence of consistent measures of the population at risk further hampers their usefulness for the purpose of monitoring trends or for studying factors associated with accidents.

State Workers Compensation systems are a third source of accident statistics. They reflect only persons covered under the respective state compensation system. Data included and the classifications by which data are presented vary from state to state, further reducing the comparability of results.

A fourth data source is the National Center for Health Statistics compilation of accidental fatalities from Coroners First Reports. Providing simply a count of fatalities, by age, state and major contributing causal factors, the data are classified to include all fatalities occurring on farms. Direct distinctions between work and nonwork fatalities are not possible but Fritsch and Zimmer have developed a methodology to provide such estimates.

The above sources use differing definitions of population at risk, and, furthermore, the criteria used to identify a recordable accident also differ. The National Safety Council defines accidents as injuries or illnesses requiring professional medical care or loss of one-half or more days from usual activities. State Worker's Compensation systems use other definitions. The Bureau of Labor Statistics, which collects data for OSHA, does not require that an injury or illness victim lose any work days or be attended by medical personnel. Obviously, OSHA records a large number of minor injuries, but they also record the number of work days lost.

The population-at-risk or an exposure time measure is probably even more difficult to ascertain than a count of injuries or illnesses suffered. In agriculture, risk exposure times by activity are not readily available. It is plausible to hypothesize that accidents per farm worker vary by activity or production process. An enlightening statistic would be accidents/activity-hour. This ratio emphasizes the fact that many employers, particularly farm workers, perform a number of different tasks throughout the year, all with varying levels of risk. Using this criterion Doss and Phister have identified farm grain and hay elevators as being associated with the highest number of injuries per activity-hour.

Summary and Research Recommendations

"As a means of adjudicating matters of personal and property rights, the adversary process has major advantages. But it is a poor replacement for making highly complex economic policy. We should compare an imperfect market with an imperfect regulatory scheme, not with some ideal and omniscient abstraction" (Schultz, p. 61).

In all models (market, judicial, insurance and regulatory) the final result is supposedly that those who demand goods and services from industries in which employment is risky must pay for the costs of employee injuries and diseases which are by-products of the production process. Obviously, coal miners, policemen, farmers and firemen will continue to be demanded despite the higher than average risks of injury and disease. The crucial question becomes whether the public policy programs of Worker's Compensation, and OSHA and, to some extent the judicial system, can allocate safety resources so as to move us closer to the socially optimal level of workplace safety.

Recommendation 1

A comprehensive review of available agricultural workplace safety statistics should be un-

dertaken. This review should include an assessment of availability of data suitable for determining causal factors contributing to accident occurrences and make recommendations for a unified data base. The focus should be limited to work-related accidents. Factors affecting the identification of work accidents, such as the dual environment of farms as places of work and places of recreation, require specific identification.

Recommendation 2

Continue to evaluate the effectiveness of the public provision of workplace safety information. Agriculture is unique in that the public sector financially supports a number of activities designed to enlighten farm workers and farmers about farm safety. The market model suggests that the well-informed worker will use knowledge of job risks to assess the attractiveness of his potential work environment and to encourage work behavior that would lower the probability of job-related accidents or diseases. Questions to which this research is directed include: Can the delivery of safety services in agriculture be improved? Does the provision of public safety information by the Extension Service provide the most cost-effective method of reducing farm accidents? How important and cost-effective is information from private sector sources such as insurance companies or the NSC?

Recommendation 3

A comprehensive evaluation of the cost and effectiveness of the current piecemeal approach to agricultural workplace safety is a prerequisite for forming a basis for developing a more integrative system of safety institutions. The current safety system has evolved somewhat haphazardly over time. Data on use of the judicial system by farm workers or employers is limited, and therefore its role as a deterrent to workplace accidents or diseases is unknown. Coverage of the agricultural sector under Worker's Compensation is still not complete in certain states. Furthermore, the relationship between experience rating of agricultural employers and farm injury rates appears weak. Product liability may have been a factor in improving the safety design of farm equipment but the relationship between the two is nebulous. OSHA standards in agriculture do not cover self-employed farm operators and currently exempt employers with fewer than ten workers. Thus the standards approach to workplace safety may have little impact on the agricultural injury rate. The question becomes, to what extent do each of these institutions impact on the level of agricultural safety at acceptable social costs.

References

Baumol, W. J., and W. Oates. *The Theory of Environmental Policy*. Englewood Cliffs, N.J.: Prentice-Hall, 1975.

Chelius, J. "The Control of Industrial Accidents: Economic Theory and Empirical Evidence." *Law and Contemp. Problems*. 38(1974):700–729.

———. "An Empirical Analysis of Safety Regulation." *Supplemental Studies*, vol. III. Washington, D.C.: National Commission on State Workman's Compensation Law, 1973.

Cornell, N., R. Noll, and B. Weingast. "Safety Regulation." *Setting National Priorities*, eds. Henry Owen and Charles Schultz, pp. 457–504. Washington, D.C.: Brookings Institution, 1976.

Daberkow, S., and C. Fritsch. *The Role of the Public Sector in Setting the Level of Workplace Safety*. USDA ESCS Economic Development Division Working Paper, in press.

Diamond, P. "Accident Law and Resource Allocation." *Bell J. Econ*. 5(74):366–405.

Doss, H., and R. Phister. *Nature and Extent of Farm Machinery Use in Relation to Frequency of Accidents in Michigan and Ohio*. Center for Rural Manpower and Public Affairs, Rep. No. 30, Michigan State University, 1969.

Ehrlich, E., and G. Becker. "Market Insurance, Self-Insurance, and Self-Protection." *J. Polit. Econ*. 80 (1972):623–648.

Fisher, D. V. *Analysis of the Rates and Provisions of Workman's Compensation Insurance Carried by Oregon Employers*. Oregon State University Agr. Exp. Sta. Circular of Info. 646, March 1974.

Fritsch, C., and J. Zimmer. *U.S. Farm Accident Fatalities*. USDA ESCS Agr. Econ. Rep., in press.

Goldberg, V. "The Economics of Product Safety and Imperfect Information." *Bell J. Econ*. 3(1974):683–688.

Gregory, P., and M. Gisser. "Theoretical Aspects of Workman's Compensation." *Supplemental Studies*, vol. I. Washington, D.C.: National Commission on State Workman's Compensation, 1973.

Howitt, R., and C. Moore. "Internalizing Health Effects of Pesticides." Paper presented at the American Agricultural Economics Association meeting, Columbus, Ohio, 10–13 Aug. 1975.

Kasper, D. "An Alternative to Workmen's Compensation." *Ind. and Labor Rel. Rev*. 28(1975):5–16.

Keefer, D. W. "Circumstances Surrounding Accidents." *Industrial Safety*, ed. Roland Blake, pp. 94–115. N.Y.: Prentice-Hall, 1953.

Kurdle, R. "Regulation and Self-Regulation in the Farm Machinery Industry." *Regulating the Product,* eds. Richard Caves and Marc Roberts, pp. 57–73. Cambridge, Mass.: Ballinger Publishing Co., 1975.

Lave, L. B. "Risk, Safety and the Role of Government." Paper presented at National Academy of Engineering Conference on Benefit-Risk Decision Making, Washington, D.C., Apr. 1971.

———. "Safety in Transportation: The Role of Government." *Law and Contemp. Problems.* 33 (1968): 512–535.

Lewis, J. H. *Coverage,* unpublished manuscript submitted to National Council of Compensation Insurance, New York, Jan. 1977.

Miller, R. "The Occupational Safety and Health Act of 1970 and the Law of Torts." *Law and Contemp. Problems.* 38(1974):612–640.

Oi, W. "On Evaluating the Effectiveness of the OSHA Inspection Program." Paper presented at Department of Labor Conference on Evaluating the Occupational Safety and Health Administration, Annapolis, Maryland, March 1975.

———. "On the Economics of Industrial Safety." *Law and Contemp. Problems.* 38(1974):3–28.

———. "Workman's Compensation and Industrial Safety." *Supplemental Studies,* vol. I. Washington, D.C.: National Commission on State Workman's Compensation, 1973.

Rosenblum, M., ed. *Compendium of Workman's Compensation.* Washington, D.C.: National Commission of State Workman's Compensation Laws, 1973.

Rowe, G. *The Hired Farm Working Force of 1977.* USDA ESCS Agr. Econ. Rep., in press.

Russell, L. "Safety Incentives in Workman's Compensation Insurance." *J. Human Resour.* 4(1974):34–51.

Schramm, C. "Workman's Compensation and Farmworkers in the United States." *Supplemental Studies,* vol. I. Washington, D.C.: Commission on State Workman's Compensation Laws, 1973.

Schultz, C. "The Public Regulation of Private Interest." *Harpers,* Apr. 1977, pp. 43–62.

Smith, R. S. "The Feasibility of an Injury Tax Approach to Occupational Safety." *Law and Contemp. Problems.* 38(1974):730–744.

———. "An Analysis of Work Injuries in the Manufacturing Industry." *Supplemental Studies,* vol. III. Washington, D.C.: National Commission on State Workman's Compensation, 1973.

———. *The Occupational Safety and Health Act.* Washington, D.C.: American Enterprise Institute for Public Policy Research, 1976.

State of New York Department of Labor. *Work Injuries Resulting from Industrial Code Violation, New York State, 1966.* Dep. Memo. 243, 1966.

State of Wisconsin, Department of Industry, Labor and Human Relations. *Inspections Effectiveness Report.* 28 Sept. 1971.

U.S. Department of Agriculture, Statistical Reporting Service. *Farm Labor.* Washington, D.C., May 1977.

U.S. Department of Commerce, Interagency Task Force on Product Liability. *Briefing Report.* Springfield, Va.: National Technical Information Service, PB-262-515, Jan. 1977.

———, Bureau of the Census. *1974 Census of Agriculture, Special Reports,* vol. 4. Washington, D.C., 1977.

———, Bureau of the Census, *1969 Census of Agriculture General Report,* vol. II. Washington, D.C., 1972.

U.S. Department of Labor, Division of Program Evaluation and Research. Occupational Safety and Health Administration. Unpublished Staff Reps. 1974 and 1976.

———, Bureau of Labor Statistics. *Chartbook on Occupational Injuries and Illnesses in 1975.* Rep. No. 501, 1977.

Economic Research Conference on U.S. Food System Regulation

Richard A. King

This conference grew out of concerns that food system regulation is not a well-defined research area, that economic regulation is a much more inclusive subject than is commonly recognized, and that regulation is likely to be a major policy issue in the years ahead. Cosponsorship by the Economics, Statistics and Cooperatives Service (ESCS), the Food System Research Group (NC-117), the Farm Foundation and the American Agricultural Economics Association (AAEA) provided a broad base for planning the agenda and for assuring representation of a wide variety of interests. This conference and the conference proceedings will contribute to raising the consciousness of the profession regarding the importance of this area of investigation and will bring new insights concerning the dimensions and complexity of the field of economic regulation.

The potential scope of economic regulation research suggested by the conference speakers is broad. Useful economic research can be done at all four stages of the development of a regulation: law making, rule making, implementation/enforcement, and litigation. Much attention has been given to the law-making aspect of regulation while the roles of rule making, implementation and litigation often have been ignored. Conference papers were selected to bring into focus these other dimensions. The decision makers (Congress, department, agency, court) differ at each stage of the process. The contrast between direct regulation of performance and indirect or market structure actions was brought out in the forum led by Fritz Mueller.

It became clear as the conference went forward that few research workers are in a position to deal effectively with every aspect of regulation. Economic researchers are located in government agencies, universities, public interest groups, corporations and trade associations. The professional setting in which one works will influence the type of research that he or she can best accomplish. Several distinct types of research—pre-legislation, post-legislation, research on agency operations and research on cumulative effects—were discussed in some detail by Dale Dahl.

Richard A. King is M. G. Mann Professor in the Department of Economics and Business, North Carolina State University–Raleigh.

The Economics of Regulation

In the opening paper, Jim Shaffer identified the key issue as: "What has to be taken into account?" Simplified models often are inappropriate representations of the regulatory process in the real world. The relevant choice is not between regulation and no regulation, but rather how the inherited regulatory system is to be modified. It is not logical to assume institutions and the distribution of wealth and power to be given, and then to use that model to conclude that a particular rule reduces total welfare. Citizen preferences are articulated both through the market and through the political process. Neither is of a higher order than the other. Both must be considered in examining the supply and demand for government regulation of economic behavior.

Bruce Gardner put supply and demand for regulation in the context of marginal social costs and marginal social benefits. He emphasized the importance of considering the distribution of costs and benefits among participant groups. In making such calculations it becomes clear that elasticities do not provide sufficient evidence; shifts in the relevant functions often are equally important. This was demonstrated in the evaluation of alternative milk pricing procedures.

Jane Campana called attention to the different perspective of lawyers and economists toward regulation—lawyers viewing regulation as the product of political processes and economists as decisions having economic impact. In her view, economic considerations will be-

come more important over time. Procedures to be followed in economic impact analysis are often specified by congressional action. To be effective, economic analysis must be translated into language that is comprehensible to lay persons. Timeliness in providing economic evidence in the rule-making process is especially critical.

Politics and Regulation

Politics and regulation provided the focus for the second series of papers. Jim Hildreth contrasted the "old" regulatory environment, in which the industry being regulated often played a dominant role, with the "new" regulatory environment in which lengthy and specific legislation often spells out procedures in great detail and provides for a functional rather than an industry orientation. Much of what passes for deregulation is the phasing out of the "old" regulatory process. Identification of the optimum amount of regulation may be difficult, but the traditional agricultural policy approach of issue identification, consideration of alternatives and specification of consequences of each is a promising place to begin.

Nina Cornell suggested that politics be viewed as a series of decisions, of communicating, having influence and winning. Informal rule making through notice and comment procedures is where the action is today. It is important to avoid economic jargon. Be brief and be relevant. Working for a decision maker often has more impact than having the role of co-equal. The record is all-important since decisions must be based only upon the evidence found there. A focus on future benefits and future costs will be more effective than historical documentation.

Tim Hammonds commented on the research needs of the regulated firm. He suggested an active posture toward evidence offered in public hearings as part of the record-building process.

Regulation Research Methods

Session three focused on regulation research methods. Dale Dahl provided an operationally useful paper, outlining in some detail four classes of regulation economics research issues. He pointed to the limited understanding of the law on the part of economists as a potential handicap in providing relevant research results. The need for more comprehensive pre-legislation research was emphasized by Tom Grumbly. He commented that intuitive processes must substitute for analysis in the absence of research. Post-legislation research on milk price policy was outlined by Boyd Buxton. His conclusion was that we are hard pressed to predict the behavior of the real world in the absence of regulation. The essence of regulation research is the comparison of outcomes expected under alternative regulatory environments.

Gary Seevers summarized the development of the Commodity Futures Trading Commission over the last four years as a new independent regulatory agency getting off the ground. He cited serious obstacles to increasing the role of economic analysis in regulatory agency operation.

Barry Bosworth detailed the sources of inflation and the prospects for containment through alternative government initiatives. He expressed concern for the decline in productivity growth and for the effect of shocks like farm price and energy price inflation on the stability of the economy. He described the new emphasis in the federal budget process on trade-offs, pointing out that many actions now lie outside the budget process. While many individual programs have small impact, the aggregate effect is important.

Regulation Research Issues

The fourth session forums provided an opportunity for small group consideration of regulation research issues by the conference participants. It was noted that familiar analytical tools may require more careful treatment when addressing regulation issues. For example, few economics texts teach students to draw marginal revenue curves so that the full range of quantities displayed on the demand curve is represented on the marginal revenue curve. Since marginal revenue is negative when price elasticity of market demand is less than one, and since the market demand for many products such as food and gasoline is inelastic, it follows in such cases that only the portion of the marginal revenue curve lying below the quantity axis is relevant for policy analysis. Graphic demonstrations found in the literature implicitly assume that demand is elastic, a convention that facilitates equating marginal cost and marginal revenue but may be inconsistent with empirical evidence.

Summary

To sum up briefly, more information about the structural and behavioral characteristics of markets is needed in order to evaluate the effects of regulatory changes in agricultural industries. New variables must be considered and better measurement tools will be required. For many purposes, identification of relevant variables and rough measures of impacts on participant groups will have a high payoff. Economists can increase their effectiveness in injecting economic findings into regulatory decision processes if they are familiar with decision-making procedures and recognize the importance of rule-making calendars.

This conference represents a way-station toward more effective regulatory analysis. Much remains to be done in providing better economic intelligence through improved methods and models. Perhaps that should be the focus of the next conference.

American Journal of Agricultural Economics

Volume 61 Number 5
December 1979 Proceedings Issue

In this issue: Proceedings from the annual meeting of the American Agricultural Economics Association held 29 July—1 August 1979 in Pullman, Washington

Editorial Council

Staff for volumes 60–62

The *American Journal of Agricultural Economics* is published five times a year (February, May, August, November, December) by the American Agricultural Economics Association. Prior to 1968, this *Journal* was the *Journal of Farm Economics*.

Printed for the AAEA by Heffernan Press, Inc., Worcester, Massachusetts, USA.

Second class postage paid at Lexington, Kentucky, and additional mailing offices, Pub. No. 019500.

Editorial Policy

The purpose of the *Journal* is to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscripts should have a relationship to the economics of agriculture, natural resources, or rural and community development. Contributions, methodological or applied, in the business, extension, research, and teaching phases of agricultural economics are equally encouraged.

Editorial Communications

All manuscripts and editorial correspondence, except as noted below, should be addressed to the editor, V. James Rhodes, Department of Agricultural Economics, Mumford Hall, University of Missouri Columbia, MO 65211

Communications concerning book reviews and books submitted for announcement in the *Journal* should be sent to the book review editor, Herbert H. Stoevener, Department of Agricultural Economics, Oregon State University, Corvallis OR 97331.

American Journal of Agricultural Economics

Volume 61 Number 5
December 1979 Proceedings Issue

AAEA Fellows and Presidents

General Sessions

Inflation, Agriculture, and the Food Economy

Specific Sessions

Valuing Nonmarket Goods: Conceptual and Empirical Issues

Small Farms Definition and Policy Research Agenda

Rural Employment and Rural-Urban Population Shifts

Nutrition and Food Policy

Issues in Freight Transportation Regulation

Abstracts

AAEA Business

Index to Volume 61

AAEA Fellows and Presidents

Fellows, 1957–79

1957
John D. Black
Thomas N. Carver
Joseph S. Davis
Garnet W. Forster
Asher Hobson
Edwin G. Nourse
Theodore W. Schultz
Henry C. Taylor
Frederick V. Waugh
Milburn L. Wilson

1958
Mordecai J. B. Ezekiel
Oscar B. Jesness
William I. Myers

1959
Harold C. M. Case
Oscar C. Stine

1960
Leonard K. Elmhirst
Sherman E. Johnson

1961
Oris V. Wells
Ernest C. Young

1962
Murray R. Benedict
Hugh B. Price

1963
Raymond G. Bressler, Jr.
Earl O. Heady

1964
Joseph A. Ackerman
Karl Brandt
Foster F. Elliott

1965
Bushrod W. Allin
George H. Aull
Willard W. Cochrane

1966
J. Carroll Bottum
George E. Brandow
Forrest F. Hill

1967
D. Gale Johnson
William Hord Nicholls
Harry C. Trelogan

1968
John F. Booth
Maurice M. Kelso
Elmer Joseph Working

1969
Nathan M. Koffsky
James G. Maddox
Walter W. Wilcox

1970
Charles Edwin Bishop
Marion Clawson
Glenn Leroy Johnson

1971
D. Howard Doane
Don Paarlberg
Rainer Schickele

1972
Karl A. Fox

1973
Harold F. Breimyer
Kenneth H. Parsons
Lauren K. Soth

1974
Dale E. Hathaway
Vernon W. Ruttan
John F. Timmons

1975
Geoffrey S. Shepherd
S. V. Ciriacy-Wantrup
Holbrook Working

1976
Emery N. Castle
Arthur T. Mosher
Willard F. Mueller

1977
Lowell S. Hardin
Austin C. Hoffman
Sidney S. Hoos
Earl R. Swanson

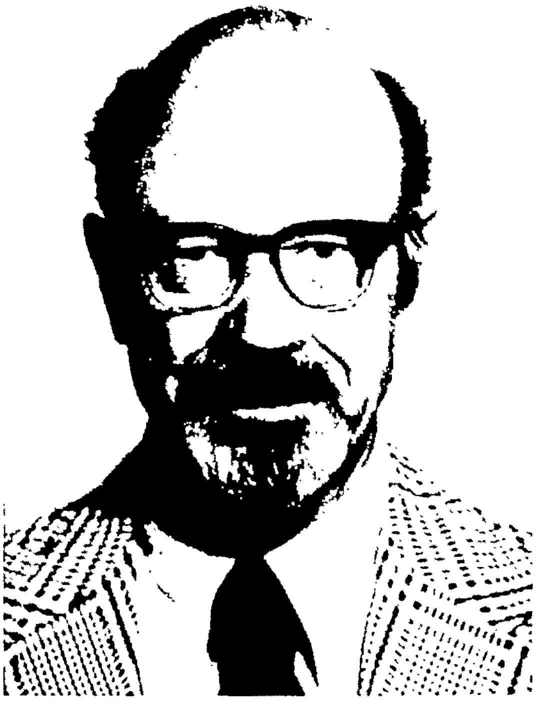
1978
Chester B. Baker
James T. Bonnen
Richard A. King
Lawrence W. Witt

1979
Varden Fuller
Ruy Miller Paiva
Kenneth L. Robinson

Varden Fuller

1979 Fellow

Professor Emeritus, University of California, Davis, 1975–present; professor, Department of Agricultural Economics, 1970–75.
Professor, Department of Agricultural and Resource Economics, University of California-Berkeley, 1948–70.
Editor, *American Journal of Agricultural Economics,* 1968–71.
Member, National Manpower Advisory Committee, 1967, 1963–65.
Social Science Research Council Fellowship, 1961–62.
Executive Secretary, President's Commission on Migratory Labor, 1950–51.



Varden Fuller has achieved national recognition as an authority on agricultural labor and for his contributions in agricultural policy and rural development. His work has been distinguished by its scholarly content, its objectivity, its high degree of perception with respect to emerging socioeconomic developments, and a vigorous and persistent concern for social change.

Born in Utah, Fuller received his A.B. degree in economics in 1934 and a Ph.D. degree in agricultural economics in 1939, both from the University of California, Berkeley.

Fuller's doctoral dissertation, "The Supply of Labor as a Factor in the Evolution of Farm Organization in California," attracted nationwide attention as one of the first objective analyses of agricultural labor supply. The dissertation refuted the long held belief that the growth of large-scale farming in California was due mainly to favorable soil and climatic conditions. Fuller's analysis revealed that continuing decades of historical episodes, with causes external to agricultural development, provided an abundant supply of low-opportunity laborers who could be obtained to do seasonal and casual farm tasks, and without overhead cost or significant recruitment effort. Thereby, impassively, appeared a profitable impetus to the large scale, labor-intensive farming system that subsequently was to become a source of strife and embattlement in rural California.

His subsequent work with the U.S. Department of Agriculture's Bureau of Agricultural Economics, while stationed in California, was concerned with displaced migrants from the Southern Great Plains and their assimilation in the Western States. His continued work in farm labor and rural development has pro-

duced a flow of highly regarded research writings and service to many national and regional bodies. This has included service as Executive Secretary to the President's Commission on Migratory Labor in 1950–51, membership on the National and the Western States Manpower Advisory Committees, and consultive advice to the U.S. Departments of Labor, Agriculture, and Interior. His writings and consultation contributed significantly to the final enactment of the California Agricultural Labor Act, the first of its kind in the nation. Many of Fuller's early proposals for improved management-labor relations and for worker fringe benefits and rights, which were originally received with some hostility by agricultural employers, are now regarded as efficient and effective personnel policies by leaders in California agriculture.

At the University of California, Dr. Fuller has had a distinguished career on two campuses. At Berkeley from 1948 to 1970, his courses in agricultural policy were noted for emphasis on political issues in agriculture. He was active in University affairs, serving on the Graduate Council as an associate in the Institute of Industrial Relations and on a wide variety of academic senate and administrative committees. In 1970 he transferred to Davis where he continued to teach agricultural policy and farm labor and expanded his early interest in rural community development.

He was editor of the *American Journal of Agricultural Economics*, 1968–71, and was for many years on the editorial board for *Industrial Relations*. To summarize, Dr. Fuller has enjoyed a long and productive career in the fields of agricultural labor, policy, and rural development.

Ruy Miller Paiva

1979 Fellow

Advisor and consultant to governments of Sao Paulo and Brazil on state and federal agricultural policy.
Published *Agriculture in Economic Development: Its Limitations as a Dynamic Factor*, 1979.
Long-time collaborator with the late William Nicholls in studies of Brazilian agriculture.
Federico Menezes Veiga award by EMBRAPA, the national agricultural research service of Brazil, 1977.
Awarded special honor by Brazilian Society of Agricultural Economists, 1970.
Cotton breeding researcher at Agronomic Institute, Campinas; chief of a rural economics subdivision, Agronomic Institute.

Ruy Miller Paiva is the father of modern agricultural economics in Brazil. More than any other individual he implanted this ''alien'' profession in his native land and nurtured it to fruition. He was an institution-builder before the importance of that concept was recognized. He contributed to agricultural policy analysis in his country when the policy-making process was dominated by the general economists. His original contributions to the literature in economic development are well known both at home and abroad.

Ruy Paiva was born in the state of Sao Paulo of American stock that had moved to Brazil from the American South after the Civil War. He was trained as an engineer-agronomo at the prestigious ''Luíz de Queroz'' College of Agriculture in Sao Paulo. His first employment was in the equally prestigious Agronomic Institute in Campinas, where he spent several years in cotton breeding research. The Institute sent him to Texas A&M to study plant science, but Ruy discovered and then shifted to the field of agricultural economics, and eventually earned the degree of Master of Science.

During the early 1940s, Ruy became chief of a small subdivision of rural economics in the Agronomic Institute. At that time there was no discipline of agricultural economics in Brazil, and general economics was dominated by the French school of distribution economics. Ruy developed a staff by taking engineer agronomos and giving them a self-help, in-service training program. They taught each other by working through texts, discussing journal articles and other sources, and working on practical problems.

Paiva himself became an important advisor on agricultural matters to the state government of Sao Paulo. As he gained recognition in government circles, so did his group of agricultural economists. Eventually transformed into one of the three Divisions of the State Secretariat of Agriculture, responsible for the policy research for the state government, this group became one of the strongest institutions of agricultural economic research in Latin America.

Ruy Paiva eventually gained national recognition, and represented Brazil in numerous international conferences. He helped develop the first national income accounts for Brazilian agriculture and became an advisor to the federal government on agricultural policy.

Paiva was a long-time collaborator of the late William Nicholls in a study of Brazilian agriculture. Scholars will be in debt to Paiva and Nicholls for many years to come for their careful measures of productivity, their penetrating insights, and the historical perspective in which they put their data. Dr. Paiva's own contribution to our understanding of technological dualism and his model of the "Auto-Control of Technological Change" has generated a lively and sustained debate in the Brazilian literature.

Paiva has been honored by his compatriots. In 1970, he was given a special honor by the Brazilian Society of Agricultural Economists in recognition of his pioneering contributions to agricultural economics in Brazil. In 1977, he was honored with the Frederico Menezes Veiga award by EMBRAPA, the national agricultural research service in Brazil. This award corresponds to the Browning Award in the United States, and is in recognition of a lifetime contribution to Brazilian agriculture.

Paiva has not rested on his laurels. He continues to play an active role in policy analysis in the Ministry of Planning, while remaining intellectually vigorous as well. His most recent book was published earlier this year. Titled *Agriculture in Economic Development: Its Limitations as a Dynamic Factor,* this monograph takes a comprehensive look at the factors which limit the expansion of agricultural output and which therefore limit the contributions which agriculture can make to the development of the general economy. As with much of his earlier work, the contribution of this monograph will most likely be in the provocative questions he asks. But provocative questions are the feedstock of continued intellectual endeavor.

Kenneth L. Robinson

1979 Fellow

Liberty Hyde Bailey Professor of Agricultural Economics, Cornell University.
Visiting professor or economist at University of California at Berkeley, University of Sydney, University of Hokkaido, and the International Institute of Tropical Agriculture.
Graduate Faculty Representative, Agricultural Economics, Cornell, 1968–70 and 1976–79.
Vice-President, American Agricultural Economics Association, 1966–67 and Editorial Council, *American Journal of Agricultural Economics,* 1965–67.
Elected the Professor of Merit by the senior class, College of Agriculture, Cornell, 1959.

Kenneth L. Robinson has been an important contributor to agricultural economics in the fields of agricultural policy and prices. He is unique in his ability to do high quality work and provide leadership in all functional areas: teaching, extension, and research. His work symbolizes the combination of academic excellence and breadth that most of us seek, but few attain. His intellect, humility, integrity, and a strong sense of public service combine to make him an outstanding individual and agricultural economist.

Raised on a fruit farm in the State of Washington, Robinson earned a bachelor's degree from Oregon State College (now University) and a master's degree from Cornell University. He was the first holder of the Elmhirst Fellowship for graduate study in agricultural economics at Oxford University, England, and completed a Ph.D. in economics at Harvard. He joined the faculty of the Department of Agricultural Economics at Cornell in 1951 and was elected the Liberty Hyde Bailey Professor of Agricultural Economics by the Board of Trustees of Cornell in 1977.

Professor Robinson is a superb teacher. He has taught one or two courses in every semester since becoming a Cornell faculty member, except when on sabbatic leave. He coauthored (with W. G. Tomek) the popular text, *Agricultural Product Prices,* and he has prepared a comprehensive set of readings for his undergraduate policy course. In recognition of his excellence as a teacher, Robinson was elected the Professor of Merit by the seniors of the College of Agriculture and Life Sciences in 1959.

Robinson also has given high priority to the education of farm and rural people. He has been a willing participant in countless exten-

sion meetings, and he has prepared a wide variety of extension materials on farm and food policy and economic outlook, including a contribution to the award-winning series, *Your Food*. He is widely respected both in New York state and nationally for his capacity to analyze and to present policy alternatives and their consequences. He is an especially effective public speaker who has contributed significantly to the economic comprehension of his audiences.

In addition to a distinguished career as a teacher and extension economist, Robinson has found time to direct the thesis research of dozens of graduate students and to do personal research and writing. Three of his students have received AAEA thesis awards. He is a careful analyst and writer and his own most demanding critic. These attributes are reflected in such frequently cited articles as "The Impact of Government Price and Income Programs on Income Distribution in Agriculture" and "Unstable Farm Prices: Economic Consequences and Policy Options."

He has contributed to the American Agricultural Economics Association as a vice-president and as a member of the editorial council. Robinson has been a visiting lecturer or professor at the University of California, Berkeley, the University of Sydney, Australia, and the University of Hokkaido, Japan, and he also was a visiting economist with the International Institute of Tropical Agriculture in Ibadan, Nigeria. He has served in numerous advisory capacities, including consulting with the Ford Foundation on its role in supporting research on domestic food and agricultural policy.

Robinson has made lasting contributions to the analysis of domestic and international policy issues through his teaching, research, and public service. Few in our profession can match the scope and depth of his accomplishments.

Presidents, 1910–80

1910–12
William J. Spillman

1913
George F. Warren

1914
Daniel H. Otis

1915
Andrew Boss

1916
Harcourt A. Morgan

1917
Henry W. Jeffers

1918
George A. Billings

1919
John R. Fain

1920
Henry C. Taylor

1921
Walter F. Handschin

1922
Benjamin H. Hibbard

1923
Thomas P. Cooper

1924
Edwin G. Nourse

1925
Milburn L. Wilson

1926
Thomas N. Carver

1927
John I. Falconer

1928
Lewis C. Gray

1929
H. E. Erdman

1930
Harold C. M. Case

1931
Oscar C. Stine

1932
John D. Black

1933
Howard R. Tolley

1934
William I. Meyers

1935
Waldo E. Grimes

1936
Joseph S. Davis

1937
Oscar B. Jesness

1938
Ernest C. Young

1939
Irving G. Davis
Foster F. Elliott

1940
Hugh B. Price

1941
Murray R. Benedict

1942
George S. Wehrwein

1943
Sherman E. Johnson

1944
Eric Englund

1945
Lawrence J. Norton

1946
Frederick V. Waugh

1947
Asher Hobson

1948
William G. Murray

1949
Oris V. Wells

1950
Warren C. Waite

1951
Forrest F. Hill

1952
George H. Aull

1953
Harry R. Wellman

1954
Thomas K. Cowden

1955
Joseph Ackerman

1956
Karl Brandt

1957
H. Brooks James

1958
Harry C. Trelogan

1959
Raymond G. Bressler, Jr.

1960
Willard W. Cochrane

1961
William H. Nicholls

1962
Bushrod W. Allin

1963
George E. Brandow

1964
Lowell S. Hardin

1965
D. Gale Johnson

1966
Kenneth L. Bachman

1967
Lawrence W. Witt

1968
C. E. Bishop

1969
Harold F. Breimyer

1970
Dale E. Hathaway

1971
Jimmye S. Hillman

1972
Vernon W. Ruttan

1973
Emery N. Castle

1974
Kenneth R. Tefertiller

1975
James Nielson

1976
James T. Bonnen

1977
Kenneth R. Farrell

1978
R. J. Hildreth

1979
Bernard F. Stanton

1980
Richard A. King

Richard A. King

1979–80 President

Fellow, American Agricultural Economics Association, 1978.
M. G. Mann Professor of Economics and Business, North Carolina State University.
Former president, Southern Agricultural Economics Association.
Visiting professor: University of Virginia, Universidad Agraria (Lima, Peru), University of California-Berkeley, North Carolina Agricultural and Technical State University, and the USDA.
Elected to Academy of Outstanding Teachers in 1967, Certificate of Merit, NCSU Chapter of Gamma Sigma Delta in 1975.
Consultant to the Research Triangle Institute, the Ford Foundation, USAID, and the Council on Wage and Price Stability.
Editorial Council, *American Journal of Agricultural Economics,* 1955–57.
Chairman: Employment Committee, 1958–61; M.S. Thesis Awards Committee, 1961–63; International Activities Committee, 1967–70, American Agricultural Economics Association.

Richard A. King holds the M. G. Mann Professorship in the Department of Economics and Business at North Carolina State University. He was born in Massachusetts and grew up in Connecticut, where he and his brother, Gordon, were active in 4-H affairs. He attended the University of Connecticut, receiving the BS degree in agricultural economics in 1946. He earned the MS degree in agricultural economics at the University of California-Berkeley in 1947. He received a Littauer Fellowship at Harvard University, completing the Master of Public Administration degree in 1948 and the Ph.D. degree in economics in 1951. He was appointed a postdoctoral fellow in political economy at the University of Chicago in 1955–56.

During the period 1944–46, King was field assistant in farm management in the Department of Agricultural Economics and Farm Management at the University of Connecticut. He served as assistant professor in that department from 1948 to 1950. In 1951, King joined the faculty at North Carolina State University as associate professor of agricultural economics engaged in teaching and research.

King was a member of the North Carolina Agricultural Mission to Peru in 1964–65 and a visiting professor in the Faculty of Social Sciences, Universidad Nacional Agraria, near Lima. He was a visiting professor in the Department of Agricultural Economics at the University of California-Berkeley in the spring

of 1969 and a member of the Food Economics Group, NEAD ESCS, U.S. Department of Agriculture in 1978. He has been a visiting lecturer at North Carolina A&T State University, at the Graduate School of Business Administration, University of Virginia, and was appointed external examiner in agricultural economics at the University of Malaya 1973–77.

Interest in the application of location theory to a variety of production, marketing, and rural community problems is reflected in King's writings. These have included a book on markets and trade with R. G. Bressler, a book on the economics of agricultural development in Peru with A. J. Coutu, and an edited collection of papers on interregional competition. He served as president of the Southern Agricultural Economics Association in 1976, and was elected a Fellow of the American Agricultural Economics Association in 1978.

He is married to the former Alfreda Smedberg from Southington, Connecticut. They have four children and live in Raleigh, North Carolina.

Choices and Consequences

Richard A. King

Choice making is at the heart of all of economics. Agricultural economists in particular—whether as classroom teachers, researchers, policy makers, or extension persons—have a long tradition emphasizing choices and consequences. However, there is always room for improvement. The annual meeting of this Association provides an opportunity to take stock, to look ahead a bit, and to find a new sense of purpose for what we do.

Economics is often defined as the study of the allocation of scarce resources among competing ends. The difficulty with this definition is that it does not focus on who is making the choices and what these choices are. We need to deal explicitly with who bears the consequences and what these consequences are. Only in a Robinson Crusoe economy do all consequences bear solely on the decision maker.

Economic theory can be an aid to choice making, but it is not an end in itself. As Hicks once said, "The place of economic theory is to be servant to applied economics." Many interesting problems cannot be attacked with an economic model that snaps from equilibrium to equilibrium as quickly as the rubber band you remove from the morning paper. The process of adjustment is at least as important as the ultimate equilibrium position, probably more important because equilibrium is never achieved. We often encounter considerable difficulty in dealing with single-valued objective functions. Public policies, however, are made in a multiple-objective setting in which equity and security considerations cannot be ignored. Attempts to draw policy recommendations directly from static, single-objective functions likely will lead to disappointment.

Economists often have a unique contribution to make in evaluating consequences. Few other specialties pay as much attention to foregone opportunities, a key element in the measurement of consequences. To say that there are externalities may be just another way of saying that our model is incomplete or that we have paid more attention to some participant groups than to others, or to some relationships than others. For these reasons it is important to identify our clientele and to understand where they come from. It is unlikely that they wish to have someone make their decisions for them but rather provide insights into the consequences to be expected from the several choices under consideration.

The remarks that follow center on some choices that are open to economists in the selection of analytical models and on the relationship between these choices and the consequences to be evaluated for individual or public clients. The topics reflect current interests of mine rather than a representative sample of pressing issues facing the profession.

This paper will deal with what I regard as serious limitations of linear expenditure models that dominate current demand literature. Applications include estimation of income elasticities, changes in elasticities over time, the relative size of income and price elasticities, and the importance of proper documentation of research results. We open with some comments on hypothesis formulation and testing.

Hypothesis Formulation and Testing

Modern computers and detailed systems models make it feasible to analyze larger sets of choices than ever before. However, such models have an insatiable appetite for input data. Time and money seldom permit estimation of all the needed underlying relationships. Earlier research that has been carefully documented can be very useful to today's model builders.

Some years ago Brandow urged agricultural economists to build their economic findings into a coherent framework. He likened the process to the trimming of a Christmas tree. My search for the exact quotation lasted well

---

President's address.

Richard A. King is M. G. Mann Professor of Economics and Business at North Carolina State University.

over a year. It finally turned up a month ago in the proceedings of a seminar held in Lincoln, Nebraska, in 1968, on the topic "Better Economic Research on the U.S. Food and Fiber Industry." Here it is:

> A lot of short-term research is just putting together something we already know to provide some meaningful answers. We need a framework within which to organize our research results. That is, we need a "Christmas tree" on which to hang the results of individual research. (1969, p. 14)

As Brandow suggested, the results of previous research ought to be carefully arranged. New work may lead to the fashioning of replacements for damaged ornaments or placing of new ornaments on parts of the tree where before there were none. Manchester urged that we take care to select a living tree to decorate, given the rapid pace of change around us.

The point to be emphasized is the need for a stock of relationships that constitute a coherent whole rather than individual ornaments to be admired. Explicit hypothesis formulation and testing is a useful device for generating these relationships. In our *Journal* last year hypotheses were explicitly stated in only five of twenty articles reporting empirical results. Popper has argued cogently that the only way for science to progress is through the formulation of refutable hypotheses (see Magee). We can never prove a hypothesis to be true, only that it can be regarded as false with a certain level of confidence.

Establishing explicit, refutable hypotheses is not sufficient. It is also important to have relevant hypotheses. Economists place undue reliance on nought for the null hypothesis. Whether this is because of the frequent use of nought in statistics courses and computer printouts or simple carelessness is open to question. In order to stir up interest in this issue, I refer to the use of nought as the null hypothesis as the "Village Idiot" hypothesis. In any case, last year in the *Journal* eighteen out of twenty studies used nought for the null hypothesis. The same was true in twenty-five of twenty-nine *American Economic Review* (*AER*) articles reviewed.

The price elasticity of demand for food will serve as an illustration. In a recent Canadian study, price elasticities for all but eight of ninety-seven food items were different from zero (Hassan and Johnson). MacGregor suggested that we test .5, 1.0, and 1.5 as alternatives to nought, providing a means for grouping foods in terms of responsiveness to price change. This is clearly a step in the right direction. More sensitive yet is the use of the elasticity estimates found in previous studies.

Immediately following Brandow's Christmas tree quotation is the following remark. "We often have not gotten significant results because we have not been explicitly framing and testing meaningful hypotheses. For example, in demand analysis we test E significantly different from zero when we should be testing E significantly different from one." It was a surprise to note that the comment was attributed to me. More than a decade later I am still selling the same old line. The argument should be more persuasive today.

What are the implications of all this? First of all, it is important that we select explicit hypotheses that have interesting implications. Second, it is seldom the case that tests of the "Village Idiot" hypothesis are particularly informative. It is not necessary to start at ground zero every time a new set of hypotheses is formulated. Third, failure to establish relevant hypotheses inhibits the growth of economic understanding.

The Question of Model Design

We are reminded by Johnston that model construction takes place at three levels: the economic model, the mathematical model, and the statistical model. Each of these three model components must be given proper weight. Selection of an appropriate economic model obviously depends on the hypotheses to be tested. Emphasis on technique—to mathematical and statistical innovation—may lead to insufficient attention being given to economic content.[1]

It may be of interest to develop an example of economic content ignored. In figure 1 we find a linear demand function $P = 10 - 2Q$ extending from the vertical price axis to the horizontal quantity axis and the corresponding marginal revenue function. Some authors draw a straight line starting at the price intercept and stopping at the quantity axis at a point one-half the distance between the origin and the quantity intercept. Question: Does

[1] In this connection, it is interesting to reread the method-methodology debates that took place at our annual meeting in 1963 and at the American Economic Association meeting the previous December.

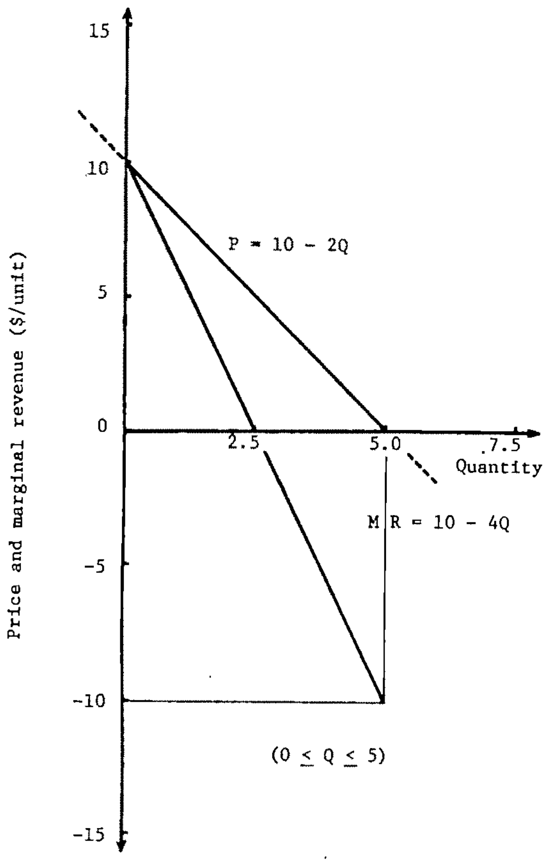


Figure 1. Marginal revenue function corresponding to linear demand function

this provide a value of marginal revenue for each Q represented on the demand function? Answer: No. Second question: Is the elasticity of demand for food larger than or smaller than 1.0? (George and King say it is $-.24$.) Where is price elasticity of demand smaller than 1? Answer: to the right of the midpoint. It follows that the food supply function intersects the food demand function three-fourths of the way down from the price intercept. If so, only the negative portion of the marginal revenue function is relevant for food policy analysis. In fact, the marginal revenue function must extend as far to the right on the quantity axis as does the demand curve.

How many of the textbooks on your shelf picture marginal revenue functions correctly? How many use negative marginal revenues when discussing choices such as livestock policy options or the effects of gasoline output changes on price and revenue? Do your students learn how to draw marginal revenue functions that include values for all relevant quantity observations? Why not find out when you meet your next class.

Let me emphasize that this is not simply a matter of accurate draftsmanship. It goes to the heart of the proper interpretation of price elasticities which for many products lie in the inelastic range. Proper specification of graphic models can be a first step to sound analysis of economic consequences.

Linear Demand Systems

Choices and consequences flowing from alternative mathematical models can best be discussed in terms of specific hypotheses. We turn first to the estimation of income elasticities from linear expenditure models. The literature on linear demand systems is very extensive but much of it is difficult to follow. The Rotterdam model, for example, is the subject of a two-volume work by Theil (1975) who has relied heavily on this model for economic forecasting. Phlips offers a very readable explanation of linear demand systems, interspersed with mathematical proofs that are heavy going for my generation of agricultural economists. Applications to food demand are reviewed by Prato and by Tomek and Robinson.

In a linear expenditure world, income elasticity can be calculated directly from marginal budget share (the slope of the expenditure function) and budget weight (expenditure divided by income), being ratio of the first to the second. With any linear expenditure function, elasticity approaches one as income increases. In the case of an expenditure function with a positive a value, elasticity approaches one from below, that is to say, it rises as income increases. For expenditure functions with a negative a value, income elasticity falls as income rises.

The relationship between expenditure functions, budget weights, and elasticities for a static two-group linear expenditure system is illustrated in figure 2. The notation follows that used by Green, Hassan, and Johnson in a very readable article in the February 1978 *Journal*. Expenditures on food and nonfood sum to total expenditure. At income levels below two nonfood expenditure is negative, offset by food expenditures that exceed total expenditure. This identifies the break between subsistence income and supernumerary income. When supernumerary income is zero,

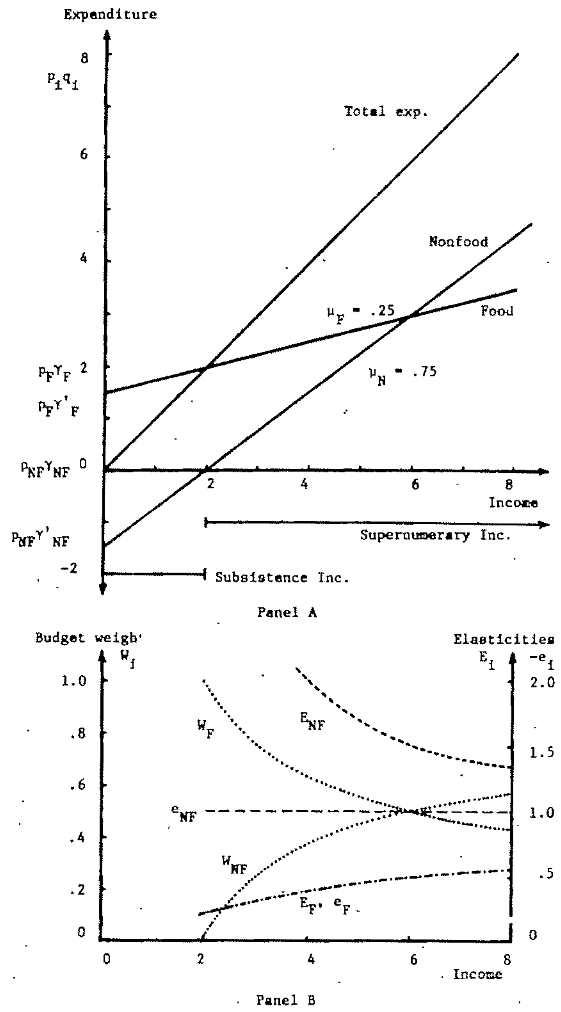


Figure 2. Expenditure functions, budget weights, and elasticities, 2-group linear expenditure system

expenditures are identified as $p_F\gamma_F$ and $p_{NF}\gamma_{NF}$. When extended back to the expenditure axis, the intercepts are $p_F\gamma'_F$ and $p_{NF}\gamma'_{NF}$.

Expenditures larger than two are allocated in fixed proportions, μ_F and μ_{NF}, of supernumerary income. The budget weight for food decreases from 1.0 while that for nonfood increases from zero as income rises from the level 2.0. Since the marginal budget shares are fixed, the income elasticity for food rises toward 1.0 and that for nonfood decreases from very large values toward 1.0 as shown in panel B of figure 2. In this simple example price elasticity for food is equal to income elasticity, but of opposite sign, while price elasticity for nonfood is constant at -1.0.

Hypotheses Concerning Income Elasticities

The article by Green, Hassan, and Johnson documents an application of linear demand systems that is useful for illustrating choices concerning hypothesis formulation. The data set comes from Canada covering the years 1947–72. Annual household expenditures were aggregated into four groups: services, nondurables, semidurables, and durables. The budget share allocated to each at average income for the period was 37¢, 34¢, 14¢, and 14¢, respectively. The marginal budget share was estimated for each group using three static linear demand systems—the Rotterdam model, the linear expenditure system (LES) and the indirect addilog system (table 1).

The question is: What is the appropriate hypothesis to test? The first possibility is that each marginal budget share is equal to zero. This hypothesis implies that the expenditure function is horizontal. Since these three mathematical models are designed so that the sum of the marginal budget shares shall equal 1, this is not a particularly informative option. A second possible hypothesis is that marginal budget share for each of the four expenditure groups is equal. That is to say, 25¢ of every additional dollar will be spent on each. A third possibility is to test, for each group, whether the marginal budget share is different from the budget share at mean income. This is a test of whether a given expenditure function passes through the origin. This third hypothesis is the appropriate test of Engel's laws concerning changes in expenditure shares.

The first hypothesis was selected, testing whether or not the marginal budget shares were different from nought. The authors concluded that this hypothesis can be rejected in every case for each of three systems. Testing the second hypothesis, that the marginal budget share for each of the four groups is equal to .25, we find that this can be rejected for two groups: services (larger than .25) and semidurables (smaller than .25). The marginal budget share for a third group, durables, is also found to be smaller than .25 as estimated by the linear expenditure system but not by the Rotterdam model.

We compare marginal budget share with budget share at mean income to test our third hypothesis. If the marginal budget share is found to be smaller than budget share at mean income, this implies that income elasticity is smaller than one and rising with income. If

Table 1. Estimated Marginal Budget Shares, Canada, 1947–72

Commodity Group	Budget Share at Mean Income	Marginal Budget Share[a] *ROT*	*LES*	*IAS*	Income Elasticity (*LES*)
Services	.374	.418*	.495*l	.469	1.32
Nondurables	.345	.229s	.237s	.252	.68
Semidurables	.143	.121*	.084*s	.085	.58
Durables	.138	.233l	.184*l	.193	1.34
	1.000	1.000	1.000	1.000	

Source: Green, Hassan, Johnson (tables 2 and 3, pp. 99 and 100).

[a] Static demand systems: Rotterdam Model (*ROT*), Linear Expenditure System (*LES*), and Indirect Addilog System (*IAS*).

Marginal Budget Share Hypotheses:

$MBS_i = 0$;
models require $\Sigma\, MBS_i = 1.00$. Rejected for all 12 coefficients.

$MBS_i = .25$;
equal response across groups. Rejection indicated by (*).

$MBS_{ij} = MBS_{ik}$;
subscripts j, k identify estimating method.

Rotterdam higher for semidurables and durables.
vs. *LES*: lower for services (*LES* = *IAS*).

Income Elasticity Hypotheses:

$E_i = 0$;
models require $\Sigma ABS_i\, E_i = 1.0$.

$MBS_{ij} = MBS_{ik}$;
implies $E_i = 1.0$; rejection of linear homogeneous expenditure function indicated by l (larger) or s (smaller).

marginal budget share is found to be larger than budget share at mean income, we know that income elasticity is larger than one and falling with income.

In the Canadian example, the LES estimates show that services and durables have marginal budget shares that are larger than budget shares at mean income. Therefore, income elasticities for services and durables are larger than one and falling with income. On the other hand, nondurables and semidurables have income elasticities that are smaller than one and rising with income. These conclusions are more relevant for evaluating choices and consequences than are tests of the hypothesis that marginal budget shares are equal to zero.

Changing Elasticities over Time

A second issue is whether price and income elasticities for food in the United States have increased or decreased over time. Several respected authors, including Breimyer, Burk, Doll, and Waugh, have argued that these elasticities have decreased over time. In a recent *Canadian Journal of Agricultural Economics* note, Hassan, Johnson, and Finley (1975) reexamined the proposition that the demand for farm products in the United States is becoming more inelastic. They suggest that this proposition has been advanced based on limited empirical evidence. Using U.S. Department of Commerce data for the period 1929–69, they find that price and income elasticities of demand for food increased over the data period. These authors used a static demand model proposed by Barten and Theil (1967) to estimate a system of equations for nine commodity groups, one of which was food.

> We find price and income elasticities less than one, as expected, but increasing over time. This result, although attributable to the fact that constant coefficients in the Theil-Barten model are being applied at increasing expenditure levels, is interesting in the sense that it suggests that this generally accepted estimation method, if applied to sample data covering a sufficiently long time period, produces results which run counter to the current thinking. (pp. 50, 52)

At least one reader was unconvinced by the evidence provided. In a comment on the Hassan-Johnson-Finley paper, deJanvry argued

> This paper is an extraordinary demonstration of the possibilities of using sophisticated mathematical economics for the purpose of public mystification. The reasoning followed is completely tautological; the models chosen imply that the stated hypothesis cannot be rejected. Yet, the mathematical complexity of the models used and their only partial explication in the article prohibit most readers from uncovering the tautology. (p. 55)

This may whet your interest in reading the remainder of the exchange for yourself. In

their reply, the authors comment that "ou paper is advanced as a basis for stimulating discussion on the question it raised" (p. 105). It does, indeed, raise questions about the relation between linear expenditure models adopted by many leading economists and consequences for policy evaluation.

Given a linear expenditure function, the relation between income, budget share, and expenditure elasticity is a mathematical identity. As we noted above, whether elasticities rise or fall as income increases is a consequence only of the intercept of the function and are readily graphed over all values of income, given the estimated expenditure function.

If an expenditure function itself rises over time, the budget share is larger and the expenditure elasticity is smaller at every level of income. The empirical problem, then, is to measure the upward shift in the function relative to the increase in income over time. Only if this upward shift is sufficiently rapid would it be possible for expenditure elasticity to fall, given that income has risen over time.

A static linear demand system has the attractive feature that the sum of expenditures on all groups equals total expenditure at every level of income. It has the unfortunate limitation that each function in the system is assumed to be unchanging over time. For this reason, the static linear demand system of Barten, Theil, and others is inappropriate for testing a hypothesis such as that considered here.

The Relation between Price and Income Elasticities

Estimates of U.S. income elasticity of demand for food reported by Hassan, Johnson, and Finley fall in the range of 0.6 to 0.8 in their two-commodity model and 0.5 to 0.8 in their nine-commodity models, well above a number of competing income elasticity estimates. That leads us to a third linear demand systems issue.

It is useful to relate income and price elasticities to one another as shown in figure 3. Income elasticity is plotted on the vertical axis and price elasticity on the horizontal axis. In quadrant II we find positive income elasticities and negative price elasticities. The 45-degree line drawn through the origin represents equal absolute values for the two.

Income elasticity for necessities is defined

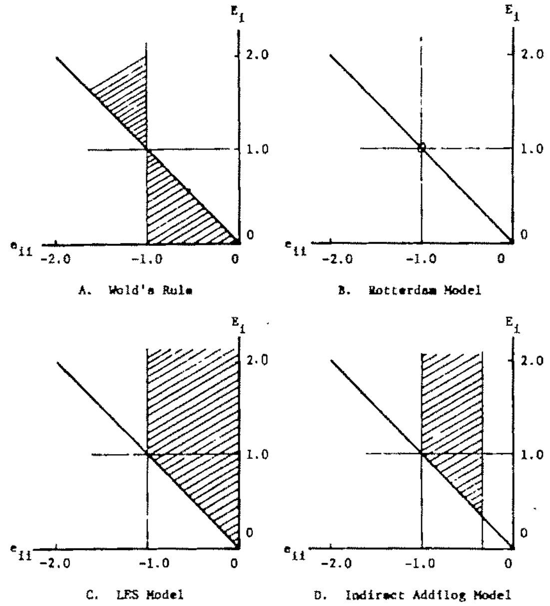


Figure 3. Income and price elasticities for selected linear expenditure models

to be smaller than 1.0 and for luxuries as larger than 1.0. The horizontal line through $E = 1.0$ shows this division. Following Tornqvist (Wold and Jureen, p. 115) we agree that price elasticity for necessities is smaller than 1.0 and luxuries is larger than 1.0. The vertical line where $e_{ii} = 1.0$ shows this division. We now have two squares in quadrant II, one for necessities and one for luxuries, and the 45-degree line dividing each in half. We are now ready to get down to business.

As a matter of fact, we are halfway through our business at this point. Formulating hypotheses that each elasticity taken individually is equal to nought leaves a lot to be desired, as Wold and Jureen demonstrated some years ago (pp. 230–4). In what follows the implications for model selection will become clearer, I trust.

Question: What is the relationship between price and income elasticities? Wold and Jureen say that "As a rule, income elasticites of necessities are smaller than their price elasticities, whereas income elasticities of luxuries are greater than their price elasticities" (p. 115). In terms of our diagram, this means that we should expect to find elasticities of necessities below the diagonal line in the square nearest the origin and to find elasticities of luxuries above the diagonal line in the upper left square (fig. 3, panel A).

Do we have empirical evidence on the rela-

tionship between price and income elasticities? Returning to the four Canadian commodity groups studied by Green, Hassan, and Johnson, we find elasticities that uniformly lie above the diagonal line (p. 100). The same is true for their nine-commodity estimates of Canadian food elasticities, whether using the Rotterdam, linear expenditure, or double-log models (p. 104). Is there something unusual about Canadian consumers in this finding that the income elasticity of food is larger than price elasticity, thereby violating Wold and Jureen's rule for necessities? Is this finding a peculiarity of the mathematical model selected?

In support of their results, Green, Hassan, and Johnson cite three other Canadian studies and three studies of U.S. food consumption, all of which report similar findings that income elasticities are larger than price elasticities (table 2). These seven sets of food demand estimates stand in direct opposition to earlier work of Brandow (1961), Waugh, and George and King who found that income elasticities were smaller than price elasticities, as expected under Wold and Jureen's rule. The implications for food policy analysis could be quite substantial if the earlier work were shown to be in error.

Can the divergence in findings be explained? Phlips (pp. 108–9) demonstrates that the Rotterdam model—in which utility is directly additive, marginal budget shares constant and income flexibility constant—requires income elasticities to be 1.0 and price elasticities −1.0 (fig. 3, panel B). According to Phlips, the reason that empirical estimates vary from these values is to be found in the finite approximation method used in the Rotterdam model estimation process. A brief explanation of why unitary income elasticities characteristic of the infinitesimal model are not obtained from the linear approximation (finite change) Rotterdam model is offered by Theil (1975, p. 105). He notes that income elasticities obtained from the Rotterdam model are not all equal to 1. However, the empirical estimates he reports are all larger than corresponding direct price elasticities.

This is not the time for detailed mathematical proofs. The general idea is quite straightforward, however. Form the ratio of income elasticity to direct price elasticity. Then investigate what is known about permissible values of that elasticity ratio, given the underlying assumptions of alternative model specifications. The formulas assembled by Green, Hassan, and Johnson are very handy for this purpose.

For values of income elasticity greater than 1.0, it is easy to show the Rotterdam model produces income elasticities that are larger than price elasticities. The elasticity ratio for income elasticities smaller than 1.0 is not as clear cut. The empirical estimates reported in the literature are found to be larger than 1.0 as well.

It can be demonstrated that the linear expenditure system (LES) requires income elasticities to be larger than price elasticities and

Table 2. Price and Income Elasticities of Demand for Food at Retail

Author	Demand System	Time Period	Price Elasticity	Income Elasticity
Canadian studies:				
Powell	Additive preference	1949–63	−0.46	0.58
Wales	Lin. exp.	1947–68	−0.27 −0.39	0.31 0.86
McIntosh	Lin. exp.	1949–68	−0.26	0.45
Green, Hassan and Johnson	Rotterdam	1947–72	−0.32 −0.42	0.55
	Lin. exp.	1947–72	−0.23 −0.30	0.39
	Double log	1947–72	−0.04 −0.20	0.86
U.S. studies:				
Hassan, Johnson and Finley (1974)	Rotterdam	1929–69	−0.33	0.64
Weiserbs	Dynamic LES	1929–70	−0.30 −0.53	0.53 0.58
Lluch and Williams	Lin. exp.	1930–72	−0.28	0.41
Brandow (1961)	Sequential	(Var.)	−0.34	0.26
Waugh	Single eqn.	1948–62	−0.24	0.14
George and King	Sequential	(Var.)	−0.24	0.18

Source: Green, Hassan and Johnson, table 8, p. 104, table 9, p. 105; George and King, pp. 40–42.

the latter must lie between 0 and -1.0 (fig. 3, panel C). This region is located between the area defined by Wold's Rule and the vertical axis. The indirect addilog system is more restrictive than LES, requiring that price elasticities lie between the negative of budget weight, $-w_i$, and -1.0 (fig. 3, panel D). (Note that both systems require marginal revenue to be negative for all commodities!)

The suggestion that the elasticities reported by Brandow (1961), Waugh, or George and King be selected as hypotheses to be rejected loses its appeal when one realizes that linear expenditure systems cannot possibly produce elasticity estimates comparable to the earlier values since these lie in the elasticity space defined by Wold's Rule, a region that is unattainable using linear expenditure models.

The consequences that follow when researchers choose among alternative mathematical models must be considered in terms of theoretical properties and uses to be made of the findings. Given my views concerning the reasonable sign for cross-price elasticities between food and other budget items, the damage caused by the requirement that income elasticities be larger than price elasticities is sufficiently great to make static linear demand systems completely unusable for food policy evaluation purposes.

After listening to these arguments against the use of linear expenditure systems, a colleague brought to my attention a line from a book by Röpke. "Only too often does mathematical economics resemble the children's game of hiding Easter eggs, great jubilation breaking out when the eggs are found precisely where they were hidden" (p. 249).

Documentation

Proper documentation of the data base can lead to wider acceptance of results and greater user confidence. It is my view that inadequate summary statistics such as means, ranges, and measures of variability are being provided in current economic literature. A review of quantitative findings reported in 1,052 pages of the 1978 *Journal* and 994 pages of *AER* in the same year confirmed my suspicions. In the *Journal* only four of nineteen articles provided mean values. In the *AER* only five of twenty-nine authors provided this information. In none of the nineteen *Journal* articles was the range of each variable provided and none provided information on variability. (A note by Smith and Snyder provided both means and ranges.) In the *AER*, two of twenty-nine articles provided ranges for a single variable while two provided standard deviations.

Last fall I was interested in providing my students with real world examples with which to practice plotting demand curves and calculating marginal revenue functions. Not a single usable function is to be found in the two journal volumes mentioned above. In a study summarizing demand relationships for California tree fruits, grapes, and nuts some 176 demand relationships are provided (Nuckton). However, I found that students would be unable to plot any of the 176 equations unless I made some assumptions as to appropriate values for each of the independent variables. Correspondence with the author indicated that mean values also went unreported in nearly all the studies that were reviewed. It may be too costly to use space in a *Journal* article to reproduce a data set. Information on means, ranges, and variability, however, would occupy very little space and in many cases could be included with the definition of variables that is customarily provided.

Reproducing a data set is not without its dangers. Some years ago we published a study of the demand for green peppers in which the data set appeared in an appendix. This data set provided one of Hildreth's graduate students an opportunity to demonstrate the folly of assembling the model as we had done. In a note of apology warning me of the forthcoming study, Hildreth commented that ours was the only published data set that could be found which was suitable for demonstrating their methodological innovation! In spite of such dangers it would be of great use in relating choices to consequences to have a complete data set provided whenever that is feasible, or comprehensive summary statistics reported when it is not.

A second set of data issues relates to accuracy, precision, and relevance. Three types of misplaced precision are to be avoided. The first is unwarranted precision. This occurs when the number of reported digits is greater than the accuracy of the data base. Numerous examples might be cited where the mean of a series or the a-value in a regression equation is reported with a larger number of digits than are to be found in the original data set.

The second type of misplaced precision is irrelevance. Irrelevant precision is typified by

t-ratios which are reported with four decimal places.

Finally, we come to unusable precision, typified by variation in the number of significant digits among the coefficients reported in a regression equation. Unusable precision was found in 90% of the articles reporting quantitative findings in the *Journal* and *AER* last year. In the *Journal* only one article reported the same number of significant digits for each coefficient (that was a study by Rausser and Stonehouse in which they used scientific notation). Articles in which the smallest number of significant digits was one reported three, four, and five significant digits for other coefficients. In articles where the smallest number of significant digits was two, the largest number ranged from four to seven. In the *AER* the results were similar. In only three of the twenty-nine *AER* articles examined were the significant digits uniform across coefficients. In fact, in two articles no significant digits were provided for at least one coefficient.

These findings I interpret as confusion between holding the number of decimal places constant and providing a uniform level of precision for all coefficients. In an attempt to provide neat summary tables we have opted for lining up decimal places rather than providing equal precision. Clearly the option taken by Rausser and Stonehouse should be used more widely. Scientific notation avoids the publication of long strings of irrelevant zeros and unusable digits.

To summarize this point, incomplete and inappropriate documentation limits the usefulness of findings for those who are interested in making choices based on quantitative estimates. For classroom teachers it is clearly time to go back to the basics, providing greater emphasis on summary statistics and their accuracy, precision, and relevance.

Change Brings New Choices

Agricultural economists are particularly open to change. Change can be seen all around us. The opening of the Erie Canal brought dramatic change to the hill farmers of New England whose homesites are now marked only by old cellar holes and ancient lilacs. The irrigated fields of the Central Valley of California once produced hides and tallow for Eastern markets while the meat was left behind to rot for lack of refrigerated transport. Interstate highways through the Appalachian mountain range have brought new market links between the Midwest and Southeast and opened new opportunities for many isolated communities.

Change brings new choices with new consequences to be weighed. But, to borrow Solow's illustration, there is always the danger that we may devote our efforts to rearranging the deck chairs on the Titantic. What do agricultural economists do best? Where does our comparative advantage lie?

Leontief had some observations on this question that bear listening to again.

> An exceptional example of a healthy balance between theoretical and empirical analysis and of the readiness of professional economists to cooperate with experts in the neighboring disciplines is offered by Agricultural Economics as it developed in this country over the last fifty years. . . . Close collaboration with agronomists provides agricultural economists with direct access to information of a technological kind. . . . Preoccupation with the standard of living of the rural population has led agricultural economists into collaboration with home economists and sociologists, that is, with social scientists of the "softer" kind. While centering their interest on only one part of the economic system, agricultural economists demonstrated the effectiveness of a systematic combination of theoretical approach with detailed factual analysis. (p. 5)

Can we maintain that "healthy balance" between theoretical and the empirical, reflect a "readiness to cooperate" with neighboring disciplines, and continue our "preoccupation with the standard of living of the rural population"? Surely we can.

Many of the choices in the 1980s will be those of the 1970s, perhaps with a new sense of urgency. What is the appropriate mix of private and public goods? How can a balance be found between goods and services for individuals and communities and those for military preparedness? What kind of an environment will we choose as measured by access to clean air, fresh water, open spaces, and sea coast? How much health shall be produced and how? How much economic security can we afford and for whom?

These questions emphasize trade-offs, trade-offs among region, socioeconomic class, time, and nation. Choices will be made through political processes and by firms and households in the light of whatever economic intelligence happens to be available. These days in Pullman offer an opportunity to gain new insights into choices and consequences

that are of particular interest to each of us and to our clientele. The potential benefits from new information flows, new models for evaluation and interpretation, and new communication methods between analyst and decision maker have never been greater.

References

Barten, A. P. "Estimating Demand Equations." *Econometrica* 36(1968): 213–51.

Brandow, George E. "Economic Research Needs for Public Policy in Food and Fiber." *Proceedings: A Seminar on Better Economic Research on the U. S. Food and Fiber Industry*, pp. 8–14. U.S. Department of Agriculture ERS, Feb. 1969.

———. *Interrelationships among Demands for Farm Products and Implications for Control of Market Supply*. Pennsylvania State University Agr. Exp. Sta. Bull. 680, Aug. 1961.

Breimyer, Harold F. "The Three Economies of Agriculture." *J. Farm Econ.* 44(1962):679–99.

Burk, M. C. *Food Expenditures by Upper Income Families*. Minnesota Agr. Exp. Sta. Tech. Bull. 269, 1969.

de Janvry, Alain. "Comment: An Intertemporal Comparison of Price and Income Elasticity of Demand for Food." *Can. J. Agr. Econ.* 24(1976):55–56.

Doll, John P., V. James Rhodes, and Jerry G. West. *Economics of Agricultural Production, Marketing and Policy*. Homewood, Ill.: Richard D. Irwin, 1968.

George, P. S., and G. A. King. *Consumer Demand for Food Commodities in the United States with Projections for 1980*. Giannini Foundation Monograph No. 26. University of California, Berkeley, Mar. 1971.

Green, Richard, Zuhair A. Hassan, and S. R. Johnson. "Alternative Estimates of Static and Dynamic Demand Systems for Canada." *Amer. J. Agr. Econ.* 60(1978):93–107.

Hassan, Zuhair A., and Stanley R. Johnson. "Direct Price Elasticity Estimates from Family Budget Data." *Can. J. Agr. Econ.* 25(1977):54–61.

Hassan, Zuhair A., S. R. Johnson, and Robert M. Finley. "An Intertemporal Comparison of Price and Income Elasticities of Demand for Food." *Can. J. Agr. Econ.* 23(1975):47–58.

———. "Further Evidence on the Structure of Consumer Demand in the U.S.: An Application of the Separability Hypothesis." *S. Econ. J.* 41(1974):244–57.

———. "Reply." *Can. J. Agr. Econ.* 25(1977):104–5.

Hassan, Zuhair A., S. R. Johnson, and Richard Green. *Static and Dynamic Demand Functions: An Application to the Canadian Data*. Agriculture Canada Pub. No. 77/14, Nov. 1977.

Johnston, J. *Econometric Methods*. New York: McGraw-Hill Book Co., 1963.

Leontief, Wassily. "Theoretical Assumptions and Nonobserved Facts." *Amer. Econ. Rev.* 61(1971):1–7.

Lluch, C., and R. Williams. "Consumer Demand Systems and Aggregate Consumption in the U.S.A.: An Application of the Extended Linear Expenditure System." *Can. J. Econ.* 8(1975):49–66.

MacGregor, Murray A. "Estimating Elasticity Coefficients of Economic Relationships." *Can. J. Agr. Econ.* 26(1978):27–28.

Magee, Bryan. *Karl Popper*. New York: Viking Press, 1973.

Manchester, Alden C. "Some Thoughts on Agricultural Marketing Research." *Agr. Econ. Res.* No. 2 (1969), 29–34.

McIntosh, C. E. "Canadian Food Expenditures in 1980." *Can. J. Econ.* 5(1972):96–109.

Nuckton, Carole F. *Demand Relationships for California Tree Fruits, Grapes, and Nuts: A Review of Past Studies*. Div. Agr. Sci., Spec. Rep. 3247, University of California, Davis, Aug. 1978.

Phlips, Louis. *Applied Consumption Analysis*. Amsterdam: North-Holland Publishing Co., 1974.

Powell, A. A. "Post-War Consumption in Canada: A First Look at Aggregates." *Can. J. Econ. and Polit. Sci.* 31(1965):559–65.

Prato, Anthony A. "Estimation of Food Demand and Consumption Relationships." *Food Demand and Consumption Behavior: Selected Research Topics*, ed. Robert Raunikar, pp. 94–115. University of Georgia Agr. Exp. Sta., Mar. 1977.

Rausser, Gordon C., and D. Peter Stonehouse. "Public Intervention and Producer Supply Response." *Amer. J. Agr. Econ.* 60(1978):885–90.

Röpke, Wilhelm. *A Humane Economy: The Social Framework of the Free Market*. Chicago: Henry Regnery Co., 1960.

Smith, Blair J., and Stephen D. Snyder. "Effects of Protein and Fat Pricing on Farm Milk Prices for the Five Major U.S. Dairy Breeds." *Amer. J. Agr. Econ.* 60(1978):126–31.

Theil, Henri. *Economics and Information Theory*. Amsterdam: North-Holland Publishing Co., 1967.

———. *Theory and Measurement of Consumer Demand*, vol. 1. Amsterdam: North-Holland Publishing Co., 1975.

Tomek, William G., and Kenneth L. Robinson. "Agricultural Price Analysis and Outlook." *A Survey of Agricultural Economics Literature: Vol. I Traditional Fields of Agricultural Economics, 1940s to 1970s*, ed. Lee R. Martin, pp. 336–51. University of Minnesota Press, 1977.

Wales, T. J. "A Generalized Linear Expenditure Model of the Demand for Non-Durable Goods in Canada." *Can. J. Econ.* 4(1971):471–84.

Waugh, Frederick V. *Demand and Price Analysis*. USDA Tech. Bull. No. 1316, 1964.

Weiserbs, D. *Data in Applied Consumption Analysis*, by Louis Phlips, p. 195. Amsterdam: North-Holland Publishing Co., 1974.

Wold, Herman, in association with Lars Jureen. *Demand Analysis: A Study in Econometrics*. New York: John Wiley & Sons, 1953.

Reprinted from
American Journal of Agricultural Economics
Vol. 61, No. 5, December 1979

Working with Other Disciplines

Earl R. Swanson

In this paper the term "discipline" simply refers to a specialized field of knowledge. Each discipline thus defined usually has a professional association and at least one journal. Equating a discipline to a profession is not completely satisfactory for all purposes, but it is consistent with common usage and convenient for the task at hand. Within a university context, a discipline corresponds approximately to an academic department, and disciplines develop when both faculty and administration come to recognize reasonably distinct areas of inquiry.

It is important to recognize that each discipline is usually composed of a set of narrower specializations and that the comprehensiveness of the discipline has at least three properties. First, there is a common conceptual model, shared to some extent by individual members of the discipline. Second, there is also a set of phenomena common to the various specializations within the discipline. Finally, it is a collection of individuals with varying specializations, and the breadth of the discipline is rarely embodied within any one scholar (Campbell, pp. 328–31). Cohesiveness of the discipline is achieved through the overlapping of the multiple narrow specialities which facilitates communication to a greater degree than is possible between disciplines.

Agricultural economists have a long tradition of relationships with other disciplines. These relationships have taken a variety of forms. For many of us, our undergraduate education included a substantial component of the natural sciences, together with an occasional sampling of the social sciences. In graduate study the contact with other disciplines frequently focuses on the so-called tools that can be used by the agricultural economist. These contacts are absorbed into our cluster of specialties and become a part of our collective professional competence. In our diverse professional activities we characteristically use data assembled by, and to some degree concepts borrowed from, other disciplines. But our profession also has a history of contributing to other disciplines as well as benefiting from them. Although it is not always apparent to our colleagues in other agricultural disciplines, our influence as an integrating discipline for the applied natural sciences in agriculture has been pervasive. The assessment of this potential by Black in 1925 was essentially accurate. Just after the passage of the Purnell Act, in a talk to the Association of Land Grant Colleges and State Universities, Black emphasized the relevance of production economics to experiment stations:

> If I had time to do it, I could show that most of the problems of an economic nature which confront our (experiment) stations, require a combination of economics and natural science analysis. All problems of the relation of input to output are of this nature, all fertilizer input studies, many feeding experiments, and cultivation experiments. (p. 662)

Our record of joint research with the natural sciences and with engineering is well documented in Association surveys of agricultural economics literature. For example, French has reviewed the marketing work that has been done with engineers and other specialists. Jensen and Woodworth have reviewed the parallel work of production economists with the biological scientists, in particular with those in agronomy and animal science. Johnson and Rausser have inventoried and evaluated simulation models, a number of which have dealt with data from natural science disciplines.

Relating of agricultural economics in a systematic way to the social sciences other than economics does not have a parallel record. For at least two decades, a recurring theme of presidential addresses, invited papers, and Fellow's lectures at our annual meetings has been the admonition to borrow from or work with other disciplines, usually other social sciences, in a problem-solving mode. These

Fellow's Address.

Earl R. Swanson is a professor of agricultural economics, University of Illinois.

The author is indebted to C. B. Baker, F. C. Fliegel, and R. J. Hildreth for comments on an early draft. Responsibility for the final version remains with the author.

speakers gave advice in different forms, but the general direction, if not the implications, of the messages is clear.

AAEA Presidents Express Need for Interdisciplinary Approach

Well over half of the presidential addresses in the last twenty years have at least mentioned the need to relate to other disciplines. Only a sample follows. Allin in 1961 told us that in order to keep farm economics relevant to its dominant purpose of improvement of the relative economic position of farm people, our intellectual interest must not be bound by blind devotion to any single social science discipline (p. 1018). In his 1967 presidential address, Bishop discussed the urbanization of rural America and noted, "While we must lean even more heavily upon economics as our parent discipline . . . , we must also become more knowledgeable about the tools of the sociologist and political scientist" (p. 1007). Breimyer also pointed out the need to borrow from sociology and political science to better understand the emerging economic structure (p. 1102).

After identifying research needs and problems, Hathaway in 1969 indicated that, "if the needed research is to be done well, most of it must be interdisciplinary, involving technical as well as economic relations and other social sciences" (p. 1021). In the 1971 invited lecture, Johnson developed in some detail the rationale for working with other disciplines. Among the incentives for such effort, he recommended that our association join other associations in sponsoring an annual award for "distinguished public administration of issue-oriented problem-solving research programs" (pp. 737–38). In his 1972 presidential address, "Economics and the Quality of Life," Castle commented that supporting multidisciplinary endeavors was popular, but that the best way to organize for such integration with simultaneous disciplinary penetration was unclear (p. 729). The need for contributions from other disciplines in rural development was pointed out by Tefertiller in 1973 (p.771), and Nielson, reflecting his experience as an experiment station director, advised in 1974: "We ought to do more to serve other disciplines and more work on disciplinary teams . . . . Frequently the biggest contribution of our profession has been to help synthesize results from other disciplines" (p. 870). Bonnen's 1975 presidential address considered needed improvements in the design of agricultural information systems. He noted that if such a system is to solve problems, it will inevitably combine and use different fields of knowledge (p. 760). As an incentive for working with other disciplines in the public policy area, Farrell suggested in his 1976 presidential address that an Association award be given for outstanding contributions within the profession to the advancement of public understanding of major policy issues, with preference to contributions that are multiunit or multidisciplinary (p. 792).

Let us conclude this sample of advice on relating to other disciplines with Bottum's counsel given in an agricultural metaphor. In his Fellow's address in 1975, "Policy Formation and the Economist," he indicated in a summary statement that we should ". . . split some new rails and spend a little less time sandpapering the old and we will have a bigger pasture. And, let's put in a gate so some of the other pertinent disciplines can join us in this enlarged pasture" (pp. 764–65).

At this point we conjecture that these numerous prescriptions reflect not only the increasing complexity of problems addressed by agricultural economists but also the trend, accentuated in the post-World War II period, toward recognizing economics as the parent discipline of agricultural economics. As Boulding noted in 1950, the success of what was then called the Ames School in agricultural economics was attributed to the discovery that there was no such subject as agricultural economics—that there was only economics applied to agriculture (p. vii). This distinction implies that we do not have our own cluster of specialties but that we are a part of another cluster—economics. In commenting on this trend, last year Paarlberg observed: "The change in our discipline has been difficult for the traditionalists . . . some of our painfully acquired skills become obsolete. But, all members of the agricultural establishment have, to a degree, in their actions if not in their words, accommodated themselves to the change" (p. 774).

Some evidence that agricultural economics has retained its distinction from economics may be found in the 1978 presidential address of Koopmans before the American Economic Association. He pointed out the need for economists to work with other disciplines in

collaborative efforts but, noted that, "to economists (collaboration) is a new challenge and a new frontier" (p. 12). For agricultural economists, and to some extent for specialists in labor economics, finance, business administration, and other areas related to economics, it is an old frontier, but nevertheless one that needs our most careful attention.

A fundamental question has been raised: Who should integrate the results of research in the separate disciplines? Should it be the specialists working together in the research process, should it be the decision maker, or someone in between? Clearly, this question cannot be answered in the abstract, but the weight of professional advice has been to shift emphasis to additional integration in the research process itself.

Although difficult to document, there has been some response to the call for interdisciplinary research articulated by Association speakers. The fact that reports from cooperative studies with other disciplines do not often appear in the *American Journal of Agricultural Economics* indicates in part that the research output from such projects does not lend itself easily to journal reporting, but also that such studies are not perceived to be in the mainstream of our profession. An informal survey of the *Journal* over the last twenty years indicates that virtually the only kind of joint research reported is that with natural scientists within colleges of agriculture.

In the remainder of this paper the focus is on the process of research with other disciplines. An improved understanding of the process should assist us to allocate our research resources and, for that fraction devoted to working with other disciplines, to improve our effectiveness.

The Nature of Cross-Disciplinary Research

Before proceeding to analyze the nature of cross-disciplinary research, we distinguish the classes of research activity along a continuum. These classes range from unidisciplinary to multidisciplinary to interdisciplinary to transdisciplinary, depending on the degree of integration, a concept introduced by Rossini et al. Note that this classification refers to a particular research activity or project and not to other relationships among the disciplines. Castle (1970) has provided a more comprehensive analysis of cross-disciplinary relationships dealing with implications for university organization. Implicit in the concept of integration is an anticipated trade-off between comprehensiveness and depth of analysis. A narrow disciplinary mix may lead to analytical depth at the expense of comprehensiveness. This balance can only be judged with respect to the objective of the particular research effort. Research output in the form of a published report is the most easily available evidence for evaluating the degree of integration.

Editorial integration in research output is the lowest level of integration. It results in a report or a set of disciplinary reports on the same topic edited without accounting for differences in terminology and concepts among the disciplines. While the report or reports may share an introduction and a conclusion, these sections are not of an integrative nature and may simply describe the history of the research project. Improvement in editorial treatment may involve consistent use of terminology throughout the study and the avoidance of isolated vocabularies. The report(s) that result from editorial integration may be considered multidisciplinary, and in the nature of a patchwork quilt. On the other hand, interdisciplinary research ideally would yield a seamless garment.

Interdisciplinary research is characterized by systemic integration. This implies that there is a common view or representation which permeates and dominates the entire research effort. Such integration may be achieved by the use of a formal model, but this should not be viewed as a stringent requirement. However, evidence of strong integrative links among the various parts of the report is required.

Finally, the upper limit of our continuum, a theoretically complete integration, has been termed transdisciplinary (Rossini et al., p. 6). This classification implies that we transcend our individual skills and disciplines and that we work with other disciplines to create a new common cognitive map of the problem. This classification remains a theoretical ideal for any study of more than a very limited scope.

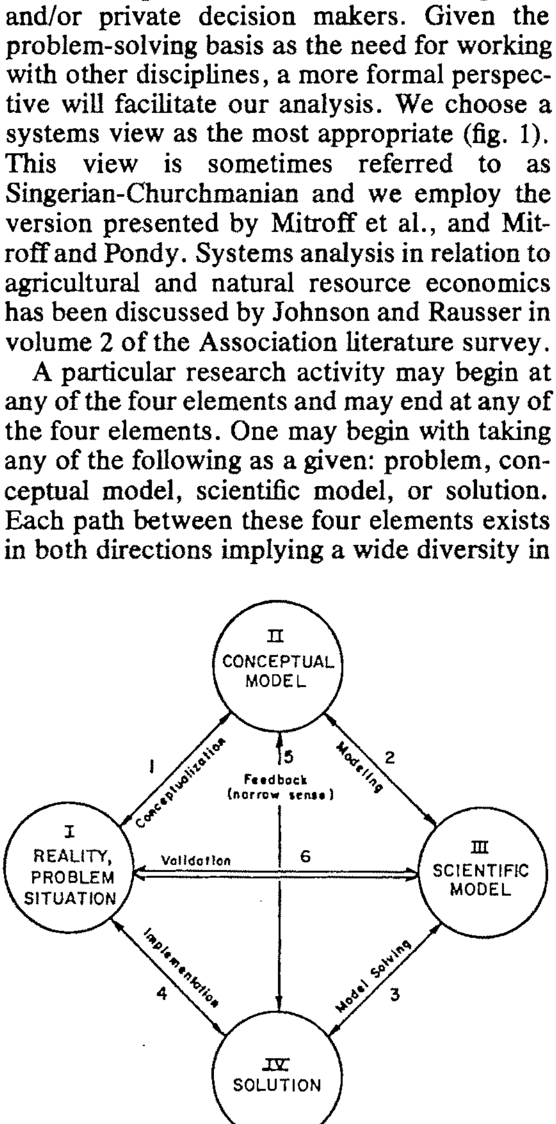
Obstacles to Cross-Disciplinary Research

If we wish to achieve the interdisciplinary or systemic level of integration in a research effort, what obstacles are to be overcome? Two related considerations are involved. The first

consists of the knowledge or epistemological problems and the second, of social elements (Petrie). The high level of interaction between these two elements implies that we find it difficult to separate them even for exposition. In this section we discuss the knowledge aspects of cross-disciplinary research.

The admonitions that we have received to work with other disciplines have been linked with problem solving, implying that the research output should be useful to public and/or private decision makers. Given the problem-solving basis as the need for working with other disciplines, a more formal perspective will facilitate our analysis. We choose a systems view as the most appropriate (fig. 1). This view is sometimes referred to as Singerian-Churchmanian and we employ the version presented by Mitroff et al., and Mitroff and Pondy. Systems analysis in relation to agricultural and natural resource economics has been discussed by Johnson and Rausser in volume 2 of the Association literature survey.

A particular research activity may begin at any of the four elements and may end at any of the four elements. One may begin with taking any of the following as a given: problem, conceptual model, scientific model, or solution. Each path between these four elements exists in both directions implying a wide diversity in



Source: Mitroff et al. p. 48.
Note: Figure 1 is reproduced with the kind permission of *INTERFACES*, published by the Institute of Management Sciences and the Operations Research Society of America.

Figure 1. A systems view of problem solving

the individual processes involved in problem solving. In fact, even the simple system of figure 1 has 3,555 total sub-systems that can be formed by considering all possible ways of combining two, three, and four elements. This number also includes the directionality of the connections between the four elements.

Although not every cross-disciplinary inquiry starts with element I, reality or the problem situation, it is appropriate for our discussion to start at that point. The first phase then requires formulation of the conceptual model. In some cases the conceptual model may be formal, a more likely occurrence in economics and the natural sciences than in the other social sciences. The conceptualization process defines and bounds the problem in broad terms, the variables that are to be considered, and the level of aggregation. Development of the scientific or formal model (III) is the next step. The modeling process includes the translation of the conceptual model into relationships which are then given greater empirical content. This is followed by the solution (IV) and, finally, implementation brings us back to an impact on the initial problem situation (I). For completeness, note that paths also exist for model validation, between I and III, and for feedback interactions between II and IV. Certainly, the ideal problem-solving loop I-II-III-IV-I is not often found in individual projects; more often a subset describes the activity.

It is tempting, and only somewhat diversionary, to classify the research efforts of agricultural economists operating in their single disciplinary mode through use of this diagram. The required skills vary among the elements and this variation represents another dimension of specialization among persons within our profession. Very few members of our profession have seriously worked in all four elements.

Among the many loops let us consider two illustrative ones, II-III-IV-II and I-II-IV-I. Those agricultural economists who follow loop II-III-IV-II are concerned primarily with the activities of modeling and model-solving. Improved solutions to more complex models with feedback in the narrow sense (fig. 1) and no immediate interest in implementation characterizes this loop. Many of our colleagues in the natural sciences operate with this loop and acknowledge this loop as the only valid form of scientific activity.

Another loop used in agricultural economics is I-II-IV-I. This loop omits element III (Scientific Model). There is confusion in this loop between conceptualization and modeling and an attempt to substitute a conceptual model for a scientific model. No matter how rich in detail the conceptual model might be, it does not, in my judgment, substitute for a validated scientific model. Omission of the scientific model implies the loss of the opportunity to develop the logical structure of the conceptual model in a systematic way and to perform the important validation process. Thus the approach implied by the I-II-IV-I loop weakens any potential implementation.

We now return to the knowledge aspects of cross-disciplinary research. In terms of our system view (fig. 1) it is necessary for participants to communicate with other, ideally, in each of the four elements—problem, conceptual model, scientific model, and solution. Perhaps the most important communication takes place with respect to the conceptual model. Each specialist can be expected to bring his own paradigm (Kuhn, Maruyama, and Johnson and Rausser) into play as he conceptualizes the problem. The degree to which core members of the research team share these paradigms is crucial in determining the level of integration in the final report.

As an example, let us consider three so-called pure paradigms (Maruyama): (*a*) unidirectional-causal paradigm, (*b*) random-process paradigm, and (*c*) mutual-causal paradigm.

There are, of course, mixtures and overlaps between and among these three paradigms as well as between these and many other paradigms. For example, the combination of *a* and *b* may describe the classical approach to production function analysis, with multiple regression forming a part of the scientific model. Suppose that an agricultural economist is using this *a-b* combination paradigm and that he is working with a biological scientist who subscribes to paradigm *c*, a mutual-causal paradigm, as a description of the system under study. Thus the biological research worker looks for feedback loops in the system and for self-cancellation or self-reinforcement based on concepts of homeostasis. Although the economist may be familiar with related concepts from general equilibrium theory, the concept of the production function from the static theory of the firm does not carry him very far toward achieving a common view with the biologist. Until they have at least moderate agreement on the paradigm, their prospects for successful interdisciplinary research are limited.

The concepts and terms from statistics may form a useful communication device. Discussion of the design of the experiment or the survey in the development of the scientific model will often lead to an improved understanding of the difference in paradigms originating in the disciplines of the participants.

Recent developments in the field of sociobiology have helped identification of certain concepts common to economics and biology (Ghiselin and Hirshleifer). Scarcity, competition, equilibrium, and specialization play similar roles in biological and economic systems. There are also certain terminological pairs—mutation/innovation, optimizing/adapting, and evolution/progress, which are common to the fields. In a sense, economics can be viewed as a subfield of sociobiology (Ghiselin). In the other direction, Becker has modified economic theory to provide an explanation for altruism among persons which parallels a biological explanation applicable to other species.

A few examples from the social sciences other than economics will indicate that there are also some common starting points for conceptualization of a given problem with these disciplines. The simple unidirection causal paradigm corresponds to a social organization that is hierarchical, while the mutual-causal paradigm implies a nonhierarchical social organization with considerable interaction among members. The equilibrium concept, a member of the mutual-causal paradigm, is also present in law (Timmons). The transaction is the unit of study in law, and the relative stability of the system's behavior is an area of inquiry. Although the more traditional political science concepts do not appear to be highly structured, they do appear to be contextual in the sense that they may utilize some variants of the mutual-causal paradigm with an embodied economics component (Nagel).

We should not underestimate the difficulty of achieving mutual understanding of paradigms between disciplines. Rossini et al. report that in a number of interdisciplinary studies, economics was the most difficult for participants from other disciplines to under-

stand. The jargon, methodological preoccupations, and world view frequently proved difficult for noneconomist research collaborators.

Without at least a minimum of the sharing of paradigms among the specialists involved in a joint research effort, the frustrations from communication are going to be very high. In particular, if the communicating parties are unaware that they are using different paradigms and are aware only of differences in vocabulary or language, each party will view the communication difficulty as resulting from the other specialist's lack of intelligence, deceptiveness, or insincerity. This leads us to the second aspect of research with other disciplines, the social process.

Organizational Alternatives

Before treating organizational alternatives for the research team itself, consideration should be given to the institutional setting (Petrie). If the research is to be both problem-solving and interdisciplinary, an academic institution is not likely to provide an ideal environment. The linking of research with graduate education leads to emphasis on loop II-III-IV-II in figure 1 which develops skills in conceptualization, modeling, and model solution, rather than the implementation phase associated with decisions made in the public and private sectors.

In order to encourage cooperative research among disciplines, a number of academic institutions have formed units outside the usual departmental pattern (Ellis, and Capener and Young). For example, special institutes have been established to study the energy problem, the environmental problem, and so forth. Less formal structures such as committees have also been employed, especially within agricultural experiment stations. The problems of a reward and incentive system that follows disciplinary lines and the attendant risks for younger staff members who participate in such interdisciplinary undertakings, have been spelled out elsewhere; in particular, in the papers by Johnson in 1971 and by Koopmans (p. 13). The most successful interdisciplinary research projects at academic institutions appear to be those that have been externally funded and that have a rather limited group, with no more than four or five disciplines represented. The institutional environment for the research team must be one that permits a substantial amount of start-up time and that has flexible hiring arrangements. It is important that institutions contemplating the support of interdisciplinary work understand its somewhat peculiar nature.

It is unlikely that a research team deliberately selects in advance the intellectual and social components that determine the organizational pattern. It is more likely that the organization evolves into a stable pattern by trial and error. Nevertheless, it is useful to identify four types of approaches to interdisciplinary research and briefly to discuss their strengths and weaknesses (Rossini et al.). These refer principally to teams containing from three to five core disciplines.

Common Group Learning

The research problem is defined and bounded by group decisions. Based on the interests and competencies of the team members, a division of effort is decided upon. Preliminary analyses are prepared and each member reads the analysis of every other member. After discussion, reports are rewritten by members who are not specialists in the area (fig. 2A). The final report is the common intellectual property of the group. This approach clearly limits the disciplinary penetration. In terms of our systems view (fig. 1), the interactions take place primarily between the problem (I) and the solution (IV).

Negotiation among Experts

The beginning of this approach is similar to common group learning, with assignments of parts to disciplinary specialists. Attempts are made to bring the full power of the appropriate discipline to bear on its assigned part, and integration takes place by negotiation (fig. 2B). Negotiation focuses only on the overlaps and linkages among the separate draft reports. The next iteration, done by the initial authors, takes into account the results of the negotiation. Nonexperts do not rewrite the separate sections of the final report. Many agricultural economists may be uncomfortable with this approach, especially when economics is competing with other disciplines as an integrator. Committees of the National Academy of Sciences and task forces of the Council for Agricultural Science and Technology often tend to follow this pattern in the preparation of assessment and state-of-the-art reports.

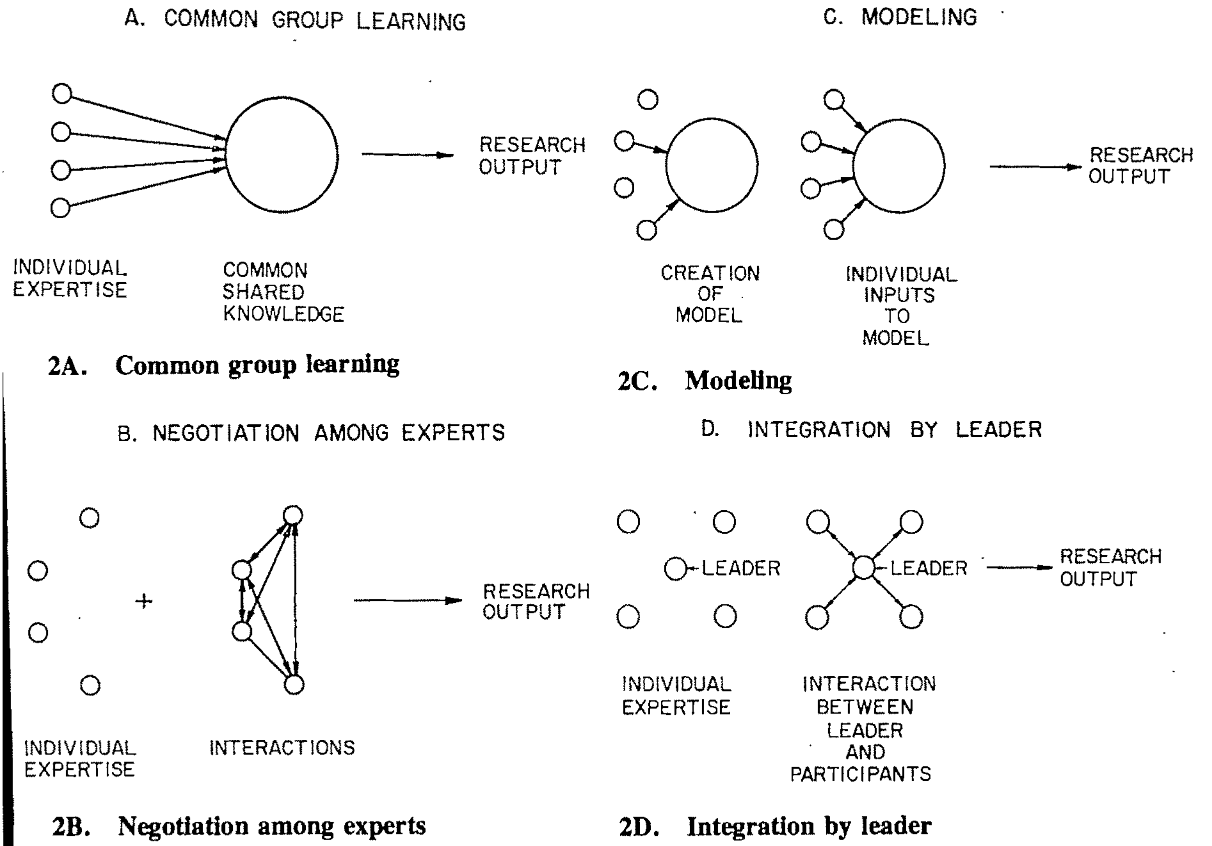


Figure 2. Organizational frameworks for cross-disciplinary research

Scientific Modeling

A formal model may serve a key integrative role. All members need not participate in model construction (fig. 2C), but ideally all should contribute data. Models often tend to narrow the research focus, but they also encourage systematic collection and analysis of data. This approach works best when closely related disciplines are involved in solving an easily defined problem. For public policy-related studies, implementation usually requires a framework broader than the model alone. Finally, the model may have the advantage of depersonalizing the process of getting input from each participant.

Integration by Leader

The problem is divided and allocated by the leader on the basis of expertise and interests of participants. The only interaction occurs between the leader and the individual team members (fig. 2D). The communication pattern is that of hub and spokes, an efficient one for communicating simple tasks in small groups (Bavelas, and Guetzow and Simon). In the other three approaches, common group learning, negotiation among experts, and modeling, the communication network needs to provide direct channels between most of the individual participants.

Each of these four ideal models implies a somewhat different kind of leadership style. Consider the following five leadership styles (Robinson and Clifford): (*a*) activator, (*b*) controller, (*c*) martyr, (*d*) cavalier, and (*e*) abdicator.

The activator uses a democratic-facilitating type of leadership in which the style is group-centered. He is active and flexible in structuring group behavior and recognizes that everyone in the group has some skill or knowledge which exceeds his own. The controller's pattern is described as autocratic or authoritarian with rigid behavior that strengthens his position in the group. The martyr is passive and hopes that the participants

will feel pity for him and perform their assigned tasks. The cavalier is permissive and, although he may entertain the participants, he cannot structure group behavior. The abdicator assumes little responsibility and behaves passively.

In the Rossini study, it was not surprising that the activator style of leadership appeared to be the most effective in terms of achieving integration in cross-disciplinary research. The second most effective was the autocratic or controller style, while the lowest level of integration was achieved with nondirective and permissive leadership styles (martyr, cavalier, and abdicator).

For the common group learning and negotiation among experts approaches, it is clear that the activator is likely to be most effective. The use of a scientific modeling approach should at least be initiated with activator leadership, but may require a shift to the controller pattern in the final stages.

The success of the integration-by-leader approach depends very much on the leader. The routine demands of administering the project may be such that, even in the unlikely event that the leader is an expert in all the separate disciplines involved, the integration will be weak and the research output multidisciplinary rather than interdisciplinary.

Four Examples

The type of research team organization that is used for a given project usually cannot be determined by reading the report of the results; participants in the research process are the only source of information. Consequently, in order to illustrate the use of the classifications and concepts presented, I now draw on some research efforts in which I have recently participated.

In the early 1970s, the college of agriculture at the University of Illinois received a grant of approximately $600,000 from the Rockefeller Foundation for the project, "Nitrogen as an Environmental Quality Factor." The funds were allocated largely on a departmental or disciplinary basis, with five major groups participating: rural sociologists, agricultural economists, agricultural engineers, agronomists, and veterinary scientists. The common theme of nitrogen and the environment was the connecting link in the five separate efforts (Deeb and Sloan, Dickey and Lembke, Swanson, Taylor, and van Blokland, van Es and Sofranko, and Welch). A book in preparation is being written by a single author. This study corresponds to our multidisciplinary category because the separate disciplines approached a common problem, and the integration was at the editorial level, not at the conceptual level. Thus, the grant provided additional funds for departments to do research on the topic but did not necessarily provide the ingredients to integrate the results. The members of the team met to discuss one another's progress only occasionally. Although useful and meaningful work came out of the project, it cannot qualify for the title "interdisciplinary."

A second project also had an environmental orientation. The project, "Soil Loss from Illinois Farms: Economic Analysis of Productivity Loss and Sediment Damage," was funded at a level of $122,000 by the Illinois Institute of Environmental Quality, a state organization. Six watersheds were studied (Guntermann, et al.). The organizational mode featured economics as the integrating discipline, and a formal model provided the scheme for integration. This organization is an example of the modeling approach discussed above. Contributing specialists included an agronomist, a hydrologist, an agricultural economist, and a finance analyst. All persons were hired to work in the department of agricultural economics, an arrangement that clarified administrative allegiance. Early establishment of a satisfactory economic model permitted the contributors to identify their own objectives and contribution to the project. The impact of the results on public policy can only be identified indirectly. A member of the Illinois Pollution Control Board mentioned that it would have been helpful if every important policy decision made by the board could have had a comparable base of information. The usefulness of the report was, in part, a result of the interdisciplinary character of the project, even though economics was the only social science discipline.

A third project, sponsored by National Science Foundation-Research Applied to National Needs, was an assessment of hail suppression technology (Changnon et al. and Farhar et al.). The eighteen-month project, carried out under a grant of $260,000, involved agricultural economists and other social scientists including sociologists, a political scientist, and a lawyer. Natural scientists included

those from atmospheric science, one of whom served as team leader, and an environmental scientist. The organizational approach was a combination of negotiation among experts and scientific modeling. Although the central economic analysis used the usual economic concepts implicit in a national spatial-equilibrium model and the theory of the firm at the individual farm level, these concepts were modified in the course of the project. The modifications represented important inputs from sociologists and the lawyer as well as others. In the preparation of the conclusions and policy recommendations, the political scientist and the lawyer had important contributions to make. Among other things, the study recommended that funds for research and development of hail suppression either be substantially increased or eliminated. As a result of the study, National Science Foundation has now discontinued the $5 million line in their budget for hail suppression research. In addition, many of the recommendations have found their way into statements of national policy (report to U.S. Secretary of Commerce from the Weather Modification Advisory Board 1978). The success in terms of policy impact was due, in a large measure, to the interdisciplinary nature of the study.

A final example is the National Defense University Long-Range Climate Project. This project proceeded in three phases. First, climatologists assessed global temperature and precipitation changes to the year 2000 for different major crop-producing areas of the world. Then, five climate scenarios were constructed. The second phase produced estimates of yield responses to weather variables made by agronomists. This permitted an assessment of the yield consequences of each climate scenario. The final phase was the input of this information into the U.S. Department of Agriculture's grain-oilseed-livestock (GOL) model to determine the impact of the five climate scenarios on location of crop production, international trade, and crop prices. Although the GOL model provided the integrating framework, the climatologists were unaware, or had only very hazy conceptions of how the GOL model operated when they made their assessments. Similarly, the agronomists were not aware of the various aspects of the GOL model when they made their crop response predictions. Nevertheless, the GOL model served as an integrating device for the total project. Organizationally, this project represents a mix of scientific modeling and integration by leader.

Conclusion

To sum up, let us first consider those research efforts in which agricultural economists work with natural sciences and engineering. In my judgment, the modeling approach or integration by leader approach are more likely to provide a satisfactory environment in which agricultural economists may contribute. However, one should not presume that what seems to be a natural integrative role for agricultural economists will be automatically perceived as such by natural scientists and engineers. These disciplines also have competing macro models (ecosystems, energy accounting systems, etc.) with integrative potential and some melding of concepts may be required.

If social scientists, in addition to agricultural economists, are included in the research team, agricultural economists may again find their contribution greater under the modeling approach with participation, as far as possible, of all team members in the modeling effort. The economic modeling may serve to integrate the important elements of the natural sciences and engineering. In many contexts, however, there is an integrating task that is beyond economics. If the research has an implementation objective such as the drafting of legislation, it is important for those responsible for that part of the project to at least be somewhat familiar with the modeling process.

An alternative approach appealing to some agricultural economists in joint research involving other social scientists is negotiation among experts. Given the preferences and skills of the individuals involved and a limited time frame, this approach may provide a better organizational structure for interdisciplinary research than one involving modeling.

In this paper an attempt has been made to describe research processes involving more than one discipline. Substantial effort, together with some compromise, is required to prevent research projects with interdisciplinary objectives from becoming multidisciplinary. Although the potential contribution from agricultural economists working with other disciplines remains high, allocation of large segments of our professional resources to such activity should be done with caution. The gains from specialization are too high to be sacrificed casually; the opportunity costs of

doing interdisciplinary research may easily be underestimated. We should recall that the objective of the Association is to further the development of systematic knowledge of agricultural economics. A part of the development of that systematic knowledge requires working with other disciplines, and it is important that we do that part well.

References

Allin, Bushrod W. "Relevant Farm Economics." *J. Farm Econ.* 43(1961):1007–18.

Bavelas, A. "Communication Patterns of Task-Oriented Groups." *J. Acoustical Soc. Amer.* 22(1950):725–30.

Becker, Gary S. "Altruism, Egoism, and Genetic Fitness: Economics and Sociobiology." *J. Econ. Lit.* 14(1976):817–26.

Bishop, C. E. "The Urbanization of Rural America: Implications for Agricultural Economics." *J. Farm Econ.* 49(1967):999–1008.

Black, John D. "Economics for Agriculture." *Selected Writings of John D. Black*, ed. James P. Cavin. Cambridge, Mass.: Harvard University Press, 1959.

Bonnen, James T. "Improving Information on Agriculture and Rural Life." *Amer. J. Agr. Econ.* 57(1957):753–63.

Bottum, J. Carroll. "Policy Formation and the Economist." *Amer. J. Agr. Econ.* 57(1957):764–68.

Boulding, Kenneth E. *A Reconstruction of Economics*. New York: John Wiley & Sons, 1950.

Breimyer, Harold F. "The AAEA and USDA in an Associationistic Age." *Amer. J. Agr. Econ.* 50 (1968):1101–12.

Campbell, Donald T. "Ethnocentrism of Disciplines and the Fish-Scale Model of Omniscience." *Interdisciplinary Relationships in the Social Sciences*, ed. M. Sherif and C. W. Sherif. Chicago: Aldine Publishing Co., 1969.

Capener, Harold R., and Robert J. Young. "Interdisciplinary Research in the University." *Nitrogen and Phosphorous: Food Production, Waste and the Environment*, ed. Keith S. Porter. Ann Arbor, Mich.: Ann Arbor Science Publishers, 1975.

Castle, Emery N. "Economics and the Quality of Life." *Amer. J. Agr. Econ.* 54(1972):723–35.

———. "Priorities in Agricultural Economics for the 1970s." *Amer. J. Agr. Econ.* 52(1970):831–40.

Changnon, Stanley A., Jr., Ray Jay Davis, Barbara C. Farhar, J. Eugene Haas, J. Loreena Ivens, Martin V. Jones, Donald A. Klein, Dean Mann, Griffith M. Morgan, Jr., Steven T. Sonka, Earl R. Swanson, C. Robert Taylor, Jon van Blokland. *Hail Suppression, Impacts and Issues. Final Report*, NSF Grant ERP75-09980. Urbana: Illinois State Water Survey, 1977.

Churchman, C. West. *The Design of Inquiring Systems*. New York: Basic Books, 1971.

Deeb, Barbara S., and Kenneth W. Sloan. *Nitrates, Nitrites, and Health*. University of Illinois Agr. Exp. Sta. Bull. 750, May 1975.

Dickey, E. C. , and W. D. Lembke. *Wells and Ponds: Water Quality and Supply*. University of Illinois Agr. Exp. Sta. Bull. 758, July 1978.

Ellis, Robert H. *The Planning and Management of Problem-Oriented, Interdisciplinary Research at Academic Institutions*. Hartford: Connecticut Rensselaer Hartford Graduate Center, 1974.

Farhar, Barbara C., Stanley A. Changnon, Jr., Earl R. Swanson, Ray J. Davis, and J. Eugene Haas. *Hail Suppression and Society. Summary of Technology Assessment of Hail Suppression*. Urbana: Illinois State Water Survey, 1977.

Farrell, Kenneth R. "Public Policy, the Public Interest, and Agricultural Economics." *Amer. J. Agr. Econ.* 58(1976):785–94.

French, Ben C. "The Analysis of Productive Efficiency." *A Survey of Agricultural Economics Literature*, vol. 1, ed. Lee R. Martin. Minneapolis: University of Minnesota Press, 1977.

Guntermann, Karl, M. T. Lee, A. S. Narayanan, and E. R. Swanson. *Soil Loss from Illinois Farms: Economic Analysis of Productivity Loss and Sedimentation Damage*. Chicago: Illinois Institute for Environmental Quality Document No. 74-62, December 1974.

Ghiselin, Michael T. "The Economy of the Body." *Amer. Econ. Rev.* 68(1978):233–37.

Guetzow, Harold, and Herbert A. Simon. "The Impact of Certain Communication Nets upon Organization and Performance in Task-Oriented Groups." *Manage. Sci.* 1(1955):233–50.

Hathaway, Dale E. "The Economics of Agricultural Economics." *Amer. J. Agr. Econ.* 51(1969):1011–26.

Hirshleifer, J. "Competition, Cooperation, and Conflict in Economics and Biology." *Amer. Econ. Rev.* 68(1978):238–43.

Jensen, Harald R. "Farm Management and Production Economics, 1946–1970." *A Survey of Agricultural Economics Literature*, vol. 1, ed. Lee R. Martin. Minneapolis: University of Minnesota Press, 1977.

Johnson, Glenn L. "The Quest for Relevance in Agricultural Economics." *Amer. J. Agr. Econ.* 53(1971): 728–39.

Johnson, S. R., and Gordon C. Rausser. "Systems Analysis and Simulation" *A Survey of Agricultural Economics Literature*, vol. 2, ed. George G. Judge et al. Minneapolis: University of Minnesota Press, 1977.

Koopmans, Tjalling C. "Economics among the Sciences." *Amer. Econ. Rev.* 69(1979):1–13.

Kuhn, Thomas S. *The Structure of Scientific Revolutions*, 2nd ed. Chicago: University of Chicago Press, 1970.

Maruyama, Magoroh. "Paradigms and Communication." *Technological Forecasting and Social Change* 6(1974):3–32.

Mitroff, Ian, and Louis R. Pondy. "On the Organization of Inquiry: A Comparison of Some Radically Different Approaches to Policy Analysis." *Public Admin. Rev.* 34(1974):471–79.

Mitroff, Ian I., Frederick Betz, Louis R. Pondy, and

Francisco Sagasti. "On Managing Science in the Systems Age: Two Schemas for the Study of Science as a Whole Systems Phenomenon." *INTERFACES* 4(1974):46–58.

Nagel, Stuart S. "Policy Studies Across the Social Sciences." *National Forum* 69(1979):9–11.

National Defense University. *Climate Change to the Year 2000, Task I; Crop Yields and Climate Change: The Year 2000, Task II; Domestic and International Policy Implications of Climate Change for the Year 2000, Task III.* Washington D. C.: National Defense University, Ft. McNair. Task I, Feb. 1978; Task II, Aug. 1978; Task III, Aug. 1979.

Nielson, James. "Accountability and Innovation: Challenges for Agricultural Economists." *Amer. J. Agr. Econ.* 56(1974):865–77.

Paarlberg, Don. "Agriculture Loses Its Uniqueness." *Amer. J. Agr. Econ.* 60(1978):769–76.

Petrie, Hugh G. "Do You See What I See? The Epistemology of Interdisciplinary Inquiry." *J. Aesthetic Educ.* 10(1976):29–43.

Robinson, Jerry W., Jr., and Roy A. Clifford. *Leadership Roles in Community Groups.* North-Central Reg. Extens. Pub. No. 36-3. University of Illinois, Coop. Extens. Serv., 1975.

Rossini, Frederick A., Alan L. Porter, Patrick Kelly, and Daryl E. Chubin. *Frameworks and Factors Affecting Integration within Technology Assessments.* Dep. Soc. Sci. Final Tech. Rep. NSF Grant ERS76-04474. Georgia Institute of Technology, 1978.

Singer, E. A., Jr. *Experience and Reflection,* ed. C. W. Churchman. Philadelphia: University of Pennsylvania Press, 1959.

Swanson, E. R., C. R. Taylor, and P. J. von Blokland. *Economic Effects of Controls on Nitrogen Fertilizer.* Illinois State University Agr. Exp. Sta. Bull. 757, Apr. 1978.

Tefertiller, K. R. "Rural Development in an Urban Age." *Amer. J. Agr. Econ.* 55(1973):771–77.

Timmons, John F. "Integration of Law and Economics in Analyzing Agricultural Land Use Problems." *Amer. J. Agr. Econ.* 37(1955):1126–42.

van Es, J. C., and A. J. Sofranko. *Environmental Decision Making: The Role of Community Leaders.* Illinois State University Agr. Exp. Sta. Bull. 756, Sept. 1977.

Weather Modification Advisory Board. *The Management of Weather Resources,* vol. 1. Washington, D.C.: Department of Commerce, Report to the Secretary, 1978.

Welch, L. Fred. *Nitrogen Use and Behavior in Crop Production.* Illinois State University Agr. Exp. Sta. Bull. 761, Feb. 1979.

Woodworth, Roger C. "Agricultural Production Function Studies." *A Survey of Agricultural Economics Literature,* vol. 2, ed. George G. Judge et al. Minneapolis: University of Minnesota Press, 1977.

Agricultural Trade: Protectionism, Policy, and the Tokyo/Geneva Negotiating Round

James P. Houck

If Shakespeare's Richard III had addressed Congress this summer, he might have opened his speech with the same line he uttered to start the drama that bears his name, "Now is the winter of our discontent." And Congress would have nodded in full agreement. The U.S. economy is tormented by persistent inflation, alarming energy shortages, and impending recession.

Major interest in trade and trade policy is focused on the fleecing we are experiencing at the hands of the Organization of Petroleum Exporting Countries (OPEC), our huge negative bilateral trade balance with Japan, and the sagging dollar. Not much front-page attention has been captured by the results of the Multilateral Trade Negotiations (MTN) which ended in April 1979, and whose implementing easily passed Congress in mid-July 1979. Yet the MTN is another important step in the evolution of the multilateral approach to world trade problems. Its implications for U.S. agricultural trade are central to this paper.

There are three main themes to follow. The first is a broad discussion of the role of agricultural trade in the world economy with some consideration of the U.S. position. The second is a rather brief look at the current trade policy/protectionism picture as it relates to trade negotiations. Third is an economic analysis of how the MTN will affect U.S. agricultural trade in the short run. Full documentation of the data and other general information used herein will not be attempted. The basic data are from well-known U.S. Department of Agriculture (USDA) sources and official publications of international agencies such as General Agreement on Tariffs and Trade (GATT), the United Nations, Organization for Cooperative and Economic Development (OCED), and the World Bank.

Invited address.

James P. Houck is a professor in the Department of Agricultural and Applied Economics at the University of Minnesota.

Research for this paper was partially supported by the Committee on Finance, U.S. Senate. Scientific Journal Series Paper No. 10,900, University of Minnesota Agricultural Experiment Station.

Agricultural Trade in Perspective

Since about 1950–54 (a benchmark period for this section), the volume of world production of all goods, agricultural and nonagricultural, has more than tripled. Since then, the volume of total world trade has more than quintupled. Consequently, the world as a whole is more dependent on and economically committed to trade than ever before.

Since 1950–54, the agricultural part of total trade has nearly tripled in volume. This trade growth has significantly outpaced the expansion in world agricultural production which has increased about 75% to 80%. Thus, nations of the world also are more dependent upon one another than ever before for food, fiber, and agricultural raw materials. However, agricultural trade has fallen from about 30% of total world trade value in 1950–54, to approximately 15% today.

Three main reasons lie behind this phenomenon. First is the pervasive tendency for farm production to grow more slowly than industrial production. This reflects the role food and fiber play in human life and the fact that these products are still generated by natural, biological processes, not mechanical and chemical ones. The second reason is that the unit values (prices) of agricultural products moving in trade have generally fallen relative to other primary products such as minerals and fuels since 1950–54 while staying approximately constant relative to manufactures. Third, complex barriers and impediments to agricultural trade have been erected over the years via national policies. These barriers do not have exact counterparts in the industrial sectors.

Composition of World Agricultural Trade and the U.S. Position

Since 1950–54, the composition of world agricultural trade has changed gradually. Food and feed products have grown from 45% of the total to almost 70% today. The major growth items have been oilseeds, feed grains, and livestock products (mainly meat). The effects of rising international affluence, the emergence of several centrally planned nations as feed and food importers, and the increasing food-deficit status of many less-developed nations have fueled this trend.

Agricultural raw materials have dwindled in relative importance from 29% in 1950–54 to about 11% today. The major items in this category display relatively stagnant markets. They are natural fibers, tobacco, and rubber. The gradual substitution of synthetic for natural materials is a major reason behind these slower growth rates.

As world markets for farm products have evolved in the past twenty-five years, the U.S. role has become larger and larger. Much of this growth is because trade demand has grown and shifted toward products in which the United States has unquestioned comparative advantage, such as grains and oilseeds. The relative decline in the value of several agricultural exporters' currencies (including the U.S. dollar) has helped to increase world demand for farm exports. But important supply factors also have been at work. For example, developments in mechanical and biological crop production technology have enhanced the natural efficiency of the United States in temperate-zone food and feed grains. Similarly, the evolution of U.S. agricultural policy during the past fifteen to twenty years has reflected the vital role exports play in generating farm income by keeping major U.S. farm exports competitive in world markets.

The net result is that the United States now accounts for about 16% or 17% of all world agricultural exports compared with about 12% in 1950–54. Our farm product imports from the rest of the world have grown much less rapidly. Consequently, the U.S. share as an agricultural importer has fallen. Our imports now account for about 8% of world agricultural trade. This is down from about 28% in 1950–54. Yet, we are still a major agricultural importing nation—behind only West Germany and Japan.

Export Products and Markets

Table 1 is a comparative profile of U.S. agricultural exports in 1953/54 and 1977/78. Note the relative growth in today's three largest categories, oilseeds (mainly soybeans), feed grains (mainly corn), and wheat. This group has virtually doubled in importance since the early 1950s with all the relative growth coming from oilseeds and feed grains. These "big ticket" commodities now represent almost two-thirds of U.S. farm exports.

Some traditional, politically important crops like tobacco and cotton have lost ground, and the myriad items in the "other" category stayed constant in proportion to the total. Many such as citrus, rice, and almonds have grown in export sales and are politically important because their production is concentrated in rather small geographic areas.

Overall, the volume of U.S. agricultural exports has almost quadrupled while farm output has increased by only 54% since 1950–54. (Oilseed and grain export volumes have grown over this period at annual rates of 10% and 7%, respectively.) Thus, a much larger share of U.S. output is being exported now than twenty-five years ago. In fact, only about 10% of cash recipts from farming came from exports in 1950–54. Now it is about 24%.

Today the bulk of U.S. agricultural export sales are for hard currencies. Only about 6% are under special government programs. Variously termed, "food for peace," "food aid," "P.L. 480," or "concessional exports," these sales have steadily dwindled in relative importance since the late 1950s and early 1960s. In the early days of Public Law 480 (the Agricultural Trade Development and Assistance Act of 1954), concessional shipments accounted for 25% to 40% of the value of our export

Table 1. Profile of U.S. Agricultural Exports, 1953/54 and 1977/78

Item	1953/54 ($3 billion)		1977/78 ($27 billion)	
	(%)			
Oilseeds and products	11	32	27	62
Feed grains	7		21	
Wheat	14		14	
Tobacco and cotton	35		11	
Livestock products	15		9	
Other	18		18	
Total	100		100	

trade, averaging about 30% in 1954–60. These special sales to food-short, politically friendly nations were very important for wheat, rice, soybean oil, cotton, tobacco, and nonfat dry milk. The nearly constant annual dollar appropriation for such sales has forced both export volume and relative importance downward since the early 1960s.

Over the past twenty-five years, the destinations of U.S. farm exports have altered to some extent but not dramatically. Changes occur slowly in the worldwide distribution of wealth, basic agricultural efficiency, the international network of farm and trade policies, and other factors influencing the direction and composition of trade flows.

The five leading buyers of U.S. agricultural exports in 1950–54 were, in order, Japan, United Kingdom, West Germany, Canada, and the Netherlands, together taking 45% of all U.S. agricultural exports. In 1977/78, the top five, in order, were Japan, the Netherlands, West Germany, Canada, and the Soviet Union (the U.K. was seventh, behind Korea). The top five in 1977/78 also accounted for 45% of all sales. Thus, at the top of the heap, no major realignments occurred with the important exception of the recent emergence of the USSR as a major market. Moreover, the nine-nation European Community (EC-9) can be viewed for most trade policy purposes as a single market. Today, it dominates all destinations, accounting for about 25%-30% of U.S. agricultural exports. Japan takes about 15%. (Incidentally, OPEC now takes 7% of the U.S. farm exports, a marked increase from very small quantities and values throughout the 1950s and 1960s.)

U.S. Agricultural Imports in Perspective

Although the dollar value of U.S. agricultural imports has more than doubled since 1950–54, the physical volume has increased by only 50%. Many tropical items do not compete with domestic farm output. These commodities (officially called complementary imports) such as coffee, tea, bananas, rubber, and cocoa now are about 40% of the total agricultural import bill, down from 60% in 1950–54. The balance is competitive at least to some extent with domestic production. Major items in this category (officially called supplementary imports) are beef, sugar, dairy products, wine, fruits, and vegetables. Of all food consumed in the United States, imports have accounted for a relatively constant 9% to 12% share in recent times.

The following list shows how imports shared in the U.S. consumption of some important items in 1976/77.

Coffee, tea, cocoa, bananas	100%
Fish	57%
Wool	50%
Sugar	43%
Fats and oils	10%
Red meat	7%
Fresh fruit (not bananas)	6%
Fresh Vegetables	6%
Dairy products	2%

Some interesting changes have occurred in the mix of imports. These are illustrated in the profile of competitive (supplementary) agricultural imports over the twenty-five year period, table 2. We now import relatively more meat, fruits and vegetables, and dairy products than we did in 1950–54. The growth in demand for hamburger meat (the principal import), the increasingly competitive supplies of off-season fruits and vegetables from Latin America, and the growth in sales of cheeses of all types are behind these increases. The inroads of synthetic fibers and the slow growth in domestic textile manufacturing caused the relative drop in wool imports. Slow demand growth and well-protected domestic production led to the relative drop in sugar's position among our major farm imports.

For competitive products, the five leading

Table 2. Profile of U.S. Imports of Supplementary Agricultural Products, 1950/54 and 1977/78

Item	1950/54 Average ($1.9 billion)	1977/78 ($7.3 billion)
	(%)	
Meat and meat products	9	22
Fruits and vegetables	6	20
Sugar	23	14
Wool	16	1
Oils and oilseeds	10	7
Dairy products	2	6
Tobacco	5	5
Wines and malt beverages	2	10
Other	27	15
Total	100	100

suppliers in 1977/78, with 38% of the total, were the Philippines, Canada, Mexico, Australia, and New Zealand.

Balance of Payments and Exchange Rates

The strong contribution that agricultural trade makes to the troubled U.S. balance of payments is well-known and needs little elaboration here. The typical measure of agriculture's net contribution is the value difference between annual agricultural exports and imports. Currently this measure is running at approximately $10–12 billion annually and has been consistently positive since 1960. If competitive farm imports only are considered in this calculation, the agricultural sector has, with only two exceptions (1936 and 1940), contributed positively to the nation's annual trade balance back at least as far as 1900.

The recent fall in the value of the U.S. dollar relative to some other currencies is a much-discussed topic with implications for agricultural trade but also extending far beyond it. The fall in the dollar's value makes our farm exports look relatively cheaper to buyers in nations whose currencies are appreciating, such as Japan, Germany, Switzerland, etc. If domestic demand in such nations can respond to lower relative prices of farm imports, consumption (hence imports) will be stimulated.

Yet U.S. farm exports have not increased to the extent that the casual observer might suppose because currency devaluation relative to the yen and the mark also has occurred for other major agricultural exporters. Hence, the U.S. market share has not boomed partly because the U.S. dollar has not fallen much or at all relative to the currencies of Canada, Australia, Brazil, and Argentina—our major competitors for world markets. In addition, farm product prices in many large import markets do not fall (or rise) in response to world market changes. Insulating trade policies in the EC-9, Japan, and elsewhere keep internal prices of many key commodities clearly detached from world levels.

National Policy and Protection

Natural differences among lands and people are powerful forces shaping the direction, magnitude, and composition of agricultural trade. The world's agricultural trade flows approach those suggested by the pure theory of international trade and the concept of comparative advantage. Yet, major distortions away from the theoretical model are evident. These result mainly from trade policies and other decisions by national governments. For agricultural products, these policies and decisions are almost always extensions of domestic agricultural and food policies. Agricultural trade policy reflects and supports fundamental commitments made by governments to domestic farmers, food industries, and (occasionally) consumers.

Barriers to agricultural trade are extremely difficult to negotiate internationally. Any change in these barriers toward more liberal trade usually undermines some national farm or food policies by making them either more costly or administratively difficult to operate. Furthermore, no nation has ever shown much willingness to negotiate the structure or terms of its own internal agricultural policy. Although they are imperfect and inconsistent everywhere, existing agricultural policies and programs have been slowly and painfully constructed. They are not altered or put aside lightly.

These rigidities are reinforced by traditional trade negotiating processes. The four major parties in worldwide agricultural (and industrial) trade are the United States, Japan, the EC-9, and Canada. If agricultural trade agreements of consequence are to be reached, one or more of these four must be involved. Each has a complex domestic agricultural policy which carries over into its trade policy in ways which severely restrict its ability to negotiate broadly on agricultural trade. Moreover, the historical tendency to treat agricultural negotiations in a separate package, largely isolated from industrial agreements adds even more rigidity to the picture.

Let us consider some important elements of food and agricultural policies in Japan, the EC-9, and Canada, insofar as agricultural trade is concerned. This will set the stage for the subsequent examination of the major MTN agreements on tariffs and quotas.

Japan

Year in and year out, Japan is the United States' largest agricultural trade customer despite a basically trade-restrictive agricultural and food policy. This is because the Japanese economy is wealthy and diversified.

Approximately 24% of Japan's 114 million people live in farm households (Sanderson, OECD 1974b). Most Japanese farms are operated as family units, but 90% of them are part-time farms. The average farm size is about 2.5 acres. Only about 6% of Japan's farms are more than 5 acres in size.

Two foundation stones of Japan's agricultural policy are rice and self-sufficiency. Rice accounts for about 35% of farm output and 33% to 34% of the total caloric intake of the people. Rice prices at the farm are supported at levels several times higher than world prices. This has far-reaching effects on all of Japan's agriculture. Input use for other crops and livestock must compete with rice. Hence, the impact of the artificially high rice price spreads throughout the agriculture and food economy creating protectionist pressures virtually everywhere.

Although dependent on foreign suppliers for food and other raw materials, Japan still maintains a strong commitment to as much self-sufficiency in food as practicable. Bitter past experience fosters this commitment. Japan is about 72% self-sufficient in all foods; this includes 100% in rice, more than 90% in vegetables and eggs, more than 80% in milk, meat, and fruit, 40% in feeds, and less than 10% in wheat and soybeans. Japanese consumers devote an average 25%–27% of their consumption expenditures to food.

Because Japan is densely populated and has only 15%–16% of its land suitable for agriculture, this rather high degree of self-sufficiency and its distribution among commodities reflect a protective agricultural policy. Much of the pressure for and support of protective policies on behalf of Japan's farmers, at the expense of consumers and taxpayers, can be traced to the special characteristics of that nation's political life as it relates to agriculture (Sanderson, Houck). By any standard, Japan's farmers are well-organized and well-situated for political action. With the generally reliable support of the Ministry of Agriculture, Forestry, and Fisheries, the various farm organizations press for and obtain economic protection on a broad front, including trade.

To implement policy decisions, Japan uses straightforward methods of controlling food imports, namely government procurement (e.g., wheat), tariffs (e.g., poultry), and quotas (e.g., beef and citrus). The allocation of quotas is handled in several ways. Generally, the quotas are parceled out to private companies, farmer coops and their affiliates, or to quasi-governmental agencies.

In addition to these formal means of control, Japan's food distribution system also forms an informal import barrier. Most food products are distributed to consumers through long chains of intermediaries closely bound to traditional (domestic) sources of supply. Thus, it can be reasonably difficult to export food products to Japan even if there are no formal barriers to entry.

The European Community (EC-9)

For all its anomalies and inconsistencies the Common Agricultural Policy (CAP) is a joint Community policy (OECD 1974a). In fact, an official publication of the EC-9 Commission observes that the CAP "was introduced in 1962 and has unfortunately remained the only real joint Community policy" (European Communities, p. 5). Without some common farm and food policy, it is unlikely that the original six-nation Common Market could have been founded initially or could remain intact today. Therefore, it is not surprising that European government officials and political leaders will do nothing in international forums and agencies to seriously undercut the fragile CAP from the outside. There are plenty of internal forces shredding its fabric from day to day.

Prior to the formation of the original Common Market, each member nation had its own complex and generally protectionist agricultural policy to which it was strongly committed. The only feasible way in the 1960s that a mutually acceptable policy, insuring substantial self-reliance in food and agricultural raw materials, could be formed was through high common prices and no direct production controls. Such a policy could be sustained only by a thoroughly protective trade policy. There simply was no other workable pathway to agreement. Even today, no apparent alternative exists except to continually repair and repatch the original scheme. Powerful farm organizations, a widespread desire for food self-reliance, the general prosperity of the Community, and the existence of chronic pockets of low farm income add rigidity to the system, effectively precluding a substantial revamping.

High rates of self-sufficiency in grains, dairy, meats, fruits, and vegetables are protected through the CAP by high internal price

guarantees. Arrived at politically, guaranteed farm prices are maintained within the EC-9 via (*a*) market intervention by government agencies for surplus products and (*b*) import controls for deficit commodities. Most of the CAP's bizarre complexities boil down to these two fundamental ideas.

When surplus production occurs, it is acquired and stored for future disposition or exported with whatever subsidy is needed to sell it abroad. For deficit products, the main import controls are (*a*) the well-known variable levies (the difference between internal, guaranteed "target" or "threshold" prices and world market prices c.i.f. Europe), (*b*) other tariffs, special adjustable levies, and some quotas. Since these measures are extensions of domestic policy, they are extremely difficult, if not impossible, to negotiate internationally under current conditions.

Because each nation in the EC-9 still maintains its own currency and much financial independence, the CAP price targets and support levels are expressed in "units of account," an artificial Community-wide accounting device. If the relative values of members' currencies are constant, "unit of account" prices can reflect market harmony throughout the Community. However, the modern floating system of international exchange rates has allowed relative currency values to fluctuate, causing "unit of account" prices to rise and fall as they are translated into specific currencies. This, in turn, spawned a complex layer of border tax adjustments which are applied to intra-Community trade in farm products. Even though the Community is now moving toward a more stable monetary system, there are still separate exchange rates among European currencies applied only to agricultural trade. This adds a baffling new tangle of complexity to the CAP. It clearly narrows the short-run ability of the Commission to negotiate internationally by further weakening the CAP's cohesiveness and undermining its basic organizing principle.

Canada

Among the developed nations, Canada occupies a unique position in the U.S. agricultural trade picture. Canada is a leading export customer for U.S. farm products and an important source of our agricultural imports. In 1977/78, Canada was the fourth leading buyer of U.S. farm exports. (Two of the three nations ahead of Canada are inside the EC-9; Japan is the third.) Similarly, Canada is our third leading source of farm imports, exceeded in 1977/78 by only Brazil and Mexico.

Like the United States, Canada's leading agricultural export customers are the EC-9 and Japan. The United States now ranks third having recently been overtaken by Japan. We buy approximately 16% of Canada's total farm exports. On the other hand, the United States currently supplies more than half of Canada's agricultural purchases.

Much of this large trade flow is due to the proximity and vast geographical size of both nations. When not excluded by trade barriers, many products can move across a long international border more economically than they can within either nation. This happens when forces of localized comparative advantage in production and marketing are not overcome by national trade policies. Trade statistics reflect this idea. They show that U.S.-Canada farm trade is very diversified among products flowing in both directions.

Broadly speaking, Canada and the United States face similar conditions domestically and in their trading relations. For example, both nations rely on agricultural trade to contribute positively to their international balance of payments. However, the agricultural export/import ratio for Canada is typically somewhat smaller than that for the United States (1.2 for Canada in 1977 as compared with 1.7 for the United States). In addition, 70% to 75% of Canada's agricultural exports are grains, feeds, and oilseed products—for the United States it is about 65%. Consequently, like the United States, Canada's trade policy and domestic farm policy are dominated by the fostering of exports and the management of grain production and inventories. The institutions and the extent of direct involvement by the government differ markedly between the two nations and among commodities. However, the problems are clearly similar.

A parallel also exists on the import side. The Agricultural Stabilization Board of Canada has the responsibility to stabilize prices and "assist the industry in realizing fair return . . ." (OECD 1973, p. 29). Under legislation, the board must support the prices of various commodities at not less than 90% of the previous five-year average market or base price with appropriate additional consideration for cash cost increases. When imports of

stabilized or supported products interfere with this policy, quota and tariff measures are readily available to Canadian authorities on a commodity-by-commodity basis. Hence, domestic agricultural policy decisions about farm prices and incomes tend to control Canadian trade policy toward imports.

If agricultural trade between the United States and Canada were as free as between our own individual states (no tariffs or quotas), it is unlikely that vast changes would occur in the basic location of production or in trade patterns. It certainly would be nothing comparable to adjustments that would occur in Japan or Europe under free agricultural trade. Consequently, the scope for trade negotiations with Canada is related not to fundamental differences in social philosophy, geography, or economic structure, but to modest differences in agricultural resources, farm support systems, and the natural tendency for an economical flow of many products to occur back and forth across a long, shared border.

International Trends in Protectionism

Going beyond the well-established network of formal trade policy, there is substantial agreement that trade protectionism is growing, even in the face of expanding trade and falling tariffs. Nontariff trade barriers of many varieties dominate this discussion. Such barriers have a long history in agricultural trade. Hillman has recently published an extensive study on this topic. He builds the case that such trade-stifling barriers (both official and unofficial) are becoming more pervasive and more effective. Middleton also documents the importance of nontariff barriers and their key role in trade negotiations. Krauss argues that this "new protectionism" is a direct result of social processes and the welfare state.

Nontariff trade barriers are difficult to negotiate internationally because they are either (*a*) official extensions of nonnegotiable domestic policies, (*b*) outside the basic purview of traditional multilateral and bilateral negotiating schemes, or (*c*) applied unofficially or covertly from deep within modern government bureaucracies. Reidel, in trying to document the current concern about nontariff protectionism, such as quotas, licensing schemes, variable duties, writes:

> On the surface, it is not at all clear that we are presently facing a 'rising tide of protectionism' as so many have declared. The available evidence is mixed. But what is occurring below the surface? This is the most disquieting aspect of the current situation, particularly because it is so difficult to monitor these developments. (p. 15)

Much of the problem in monitoring protectionism today stems from its unofficial character. Reidel also ponders:

> Because of the secrecy that surrounds unofficial arrangements to restrain trade, there is no reliable way of monitoring these actions or assessing their significance. . . . Are these reported cases [of unofficial arrangements] no more than the tip of an evergrowing iceberg? (pp. 6–7)

The basic objectives and final results of the Tokyo/Geneva MTN Round, discussed next, reflect a serious effort to manage and possibly reduce the effects of nontariff trade barriers in both industrial and agricultural trade.

The Tokyo/Geneva Round in Brief

The official chronology shows that the seventy-nine month Tokyo/Geneva Round, concluded in April 1979, was the lengthiest formal trade negotiation in GATT history. The previous recordholder was the 1963–67 Kennedy Round, which lasted fifty-four months. The five GATT negotiating sessions before the Kennedy Round were comparatively short because tariff cuts and tariff bindings were the only major issues. Nontariff trade barriers were largely bypassed.

Agricultural trade issues have formed a large part of the recent negotiations. As mentioned earlier, such discussions are not completed quickly or easily. In addition, both the Kennedy Round and the Tokyo/Geneva Round produced some rather delicate changes in the basic legal and institutional framework of the GATT itself. Also, difficult negotiations on codes of conduct through which the agreement is implemented in practice and through which nontariff barriers are attacked were conducted.

The Legacy of the Kennedy Round

As in the Tokyo/Geneva Round, official statements were continually advanced in the Kennedy Round about the crucial importance of agriculture from the U.S. viewpoint. Here,

as quoted by Schnittker, is a typical example from a 1963 speech by Christian A. Herter, the U.S. Chief Negotiator for the Kennedy Round. "It is, of course, the firm position of my government that negotiations must include agricultural products. This means that my government will not be prepared to conclude the negotiations until equitable tariff and trade arrangements have been developed for agricultural products." However, major breakthroughs in agricultural trade negotiations simply did not materialize in the Kennedy Round. Those familiar with its history know that the major parties were simply too far apart and too inflexible within their own domestic policy constraints to maneuver toward anything new. At the 1967 conclusion of the Kennedy Round, the political commitment for substantive agricultural agreements was deemed to have been satisfied in two main ways (USDA 1967). First, an International Grains Arrangement was signed. It was an outgrowth of previous International Wheat Agreements and contained a Food Aid Convention and an ill-fated, price-fixing trade convention for wheat. Second, a set of tariff cuts and bindings was concluded for agricultural products whose trade coverage, at that time, was $866 million on the U.S. export side and $860 million on the import side. (Incidentally, at 1978/79 price levels, these trade coverage values would now approximate $2.0 billion. This can be compared with trade coverage values in the $3.0–4.0 billion range now being discussed in connection with current agreements.)

Herter's statement, quoted above, is remarkably similar to our official stance in the Tokyo/Geneva Round, which is buttressed by similar language in the Trade Act of 1974, authorizing U.S. participation in the round (U.S. Congress 1975). As with the Kennedy Round, agricultural agreements were again difficult to arrange and the final results are modest.

Major Agricultural Participants in the Tokyo/Geneva Round

Under negotiating procedures evolved in GATT since 1947, multilateral tariff and trade concessions for commodities and industrial sectors occur only when two or more of the leading trading nations in the relevant products are able to agree on the main terms of a settlement. Then other interested parties can join in and, by their participation, round out a multilateral package in which all GATT members may share.

In the Tokyo/Geneva Round, much as with the Kennedy Round, center stage in the agricultural negotiations was occupied by the United States, the European Community, and Japan. (Though important in earlier rounds, the United Kingdom is now submerged within the EC-9.) Other important nations on the inner fringe, next to the "big three," are Canada, Mexico, Brazil, Argentina, and Australia. These few nations form the pool from which pairs and other combinations must be drawn for any significant dealing to occur.

Results of the Tokyo/Geneva Round

The objectives of the round were set out in the so-called Tokyo Declaration of September 1973, which formally opened the negotiations (U.S. Congress 1975). Much has been published on the general objectives and the extent to which they were achieved as the negotiations unfolded (U.S. Department of State; USDA 1979; U.S. Congress 1979 a, b; Livernash; Twigs; Golt). However, three main categories of agricultural agreements can be identified from the economist's point of view.

First are the specific tariff and trade barrier agreements similar to those which have been the core of previous rounds. These were achieved within the traditional bilateral "offer and request" framework. Second are the behavioral codes, the most important of which for agriculture are the "export subsidies/countervailing duty" code and the "standards" code. The former seeks to tighten international responsibility and restraint insofar as export subsidies and retaliation are concerned; the latter is designed to reduce the use of various standards, product certification, and testing as barriers to trade. Third are international agreements for consultations on dairy products, beef, and general agricultural policy. These agreements have no substantive economic provisions.

Evaluation of the economic effects of the new codes and the international consultative agreements is completely subjective at this time. Their potential value lies in their ability to reduce and help manage trade conflicts. Interest groups and individuals, public and private, are now having their say about this, and they disagree. However, it is possible to estimate the net economic effects of the new tariff

and quota agreements with some standard tools of economic analysis. That is the subject of the balance of this paper.

Economic Analysis of the MTN Agreements for Agricultural Tariffs and Quotas

In the negotiations, three main bilateral packages with Japan, EC-9, and Canada were achieved. In addition, lesser agreements involving about thirty other nations were signed covering both tariff and nontariff items. On the export side, we will look at the three main packages separately and then consider the others as a single group. On the import side, we will consider U.S. agricultural concessions as a group.

The Method

The method used to calculate new trade values resulting from tariff changes comes from partial equilibrium analysis. For any given product, let

$$(1) \qquad I = C - S,$$

where I is volume of imports, C is volume of domestic consumption, S is volume of domestic production. Then, if P is the domestic price observed at the import level,

$$(2) \qquad \frac{\partial I}{\partial P} = \frac{\partial C}{\partial P} + \frac{\partial S}{\partial P}.$$

Then, by making appropriate multiplications and divisions, equation (2) can be restated in a general elasticity form as follows:

$$(3) \quad \frac{\partial I}{\partial P}\,\frac{P}{I} = \left[\frac{\partial D}{\partial P}\,\frac{P}{D}\right]\frac{D}{I} - \left[\frac{\partial S}{\partial P}\,\frac{P}{S}\right]\frac{S}{I}, \text{ or}$$

$$(4) \qquad E_I = E_D(D/I) - E_S(S/I),$$

where E_I is price elasticity of import demand, E_D is price elasticity of domestic demand, E_S is price elasticity of domestic supply. For purposes of this analysis, E_S was taken to be equal to zero in all cases. This rules out specific consideration of domestic supply response or stock adjustments to changed prices as tariffs change. Thus,

$$(5) \qquad E_I = E_D\,(D/I).$$

The import demand elasticity is the domestic demand elasticity (obtained from various empirical research studies) weighted by the ratio of consumption to imports, this ratio being greater than or equal to 1.0.

Finally, the percentage change in imports (% ΔI) was calculated as

$$(6) \qquad (\%\ \Delta I) = E_I\,(\%\ \Delta P),$$

where (% ΔP) is the estimated percentage change in domestic price as the result of a specified tariff change. This assumes that these import demand shifts do not alter world FOB or c.i.f. prices—a plausible assumption in this context. To obtain the dollar value of "new" trade, the result of equation (6) was applied to the 1976 base trade figures, used by the office of the Special Trade Representation (STR) for negotiating purposes, on the assumption that the United States maintains its 1976 market share of all import markets.

The value of quota changes was estimated by assuming that the new specific quotas would be filled at current world price levels by U.S. suppliers. Both the tariff and quota analyses focus on the total adjustments as negotiated without considering the intermediate staging that will occur in their actual application beginning in 1980.

Japan

The U.S.-Japan settlement insofar as agriculture is concerned has three major components. First is a set of tariff bindings. Second is a series of tariff reductions granted by Japan on about sixty-seven listed categories of items, widely diversified. Third are increases in Japanese import quotas of a few tightly controlled items.

Tariff bindings. Tariff bindings covered some fourteen items whose 1976 base trade value is \$809 million. These bindings are scattered over a number of product groups. However, the "free" binding on soybeans alone accounts for \$770 million, or 95% of this total. It is impossible to calculate or predict the value of this trade concession. Most observers value this concession highly and feel that a similar "free" binding on soybeans obtained from the European Common Market during the 1962 Dillon Round, and sustained since then, has been partially responsible for that market's huge growth.

Tariff cuts. Excluding bound items, the new tariff reductions average 35% across the board. For purposes of analysis, the tariff reductions were assumed to exert downward

pressure on retail and wholesale prices inside Japan. The economic value of a tariff reduction occurs because the total market for the general product expands and because the market share of imported items grows due to their relative price reduction.

Table 3 summarizes the results of calculations on the trade effects of the negotiated tariff changes. They are to be viewed as approximations indicating relative magnitudes; they are not precise predictions because, among other things, they isolate only the effect of tariff changes.

Almost 40% of the estimated trade increase is concentrated in the pork market. The calculation assumes that imported pork actually will fall in relative price because of the negotiated settlement. However, Japanese imports of pork are also subject to a complex duty formula which resembles a variable import levy. Consequently, this part of the calculation could be nullified if the relative price of imported pork is not permitted to decrease despite the nominal tariff cut. The totals show that trade values increase by an estimated $92 million or about 21% of the base value of the covered items. Without pork, the $57 million increase represents 19% of the base value of covered items.

Quota increases. The U.S.-Japan settlement contained import quota relaxation for four commodities in which the United States has a sizable, direct interest: high-quality beef, oranges, orange juice, and grapefruit juice. Table 4 illustrates the current quotas, the full relaxation implied in the settlement, and the estimated trade value of the quota increases.

Japan summary. Estimated values of the

Table 3. MTN Tariff Packages: Summary of U.S. Agricultural Export Increases under Full Tariff Reductions as Negotiated

Item	Base Trade Value (1976)	New Value	Change (+)
	(US$ million)		
Japan			
Fruits and vegetables	168	197	29
Poultry	16	29	13
Pork	150	185	35
Others	110	125	15
Total	444	536	92
EC-9			
Rice	124	130	6
Offals	117	159	42
Hormone products (livestock)	53	79	26
Tobacco	411	423	12
Animal oils	18	22	4
Fruits and vegetables	91	99	8
Turkey legs	5	7	2
Others	48	50	2
Total	867	969	102
Canada			
Pork	158	202	44
Tobacco and products	7	11	4
Live animals	68	71	3
Orange juice	38	39	1
Potatoes	25	26	1
Others	117	120	3
Total	413	469	56
Other nations			
Vegetable oils (Dom. Rep.)	4	6	2
Soybean meal (Korea)	—	2	2
Others	43	48	5
Total	47	56	9
Grand Total	1,771	2,028	257

Table 4. MTN Quota Agreements: Summary of Changes and Estimated Annual Trade Value

Item	Original Quota	New Quota	Change (+)	Annual Value of Change
	(million pounds)			($)
Japan				
Beef	37.0	67.9	30.9	77.3 mil.[a]
Oranges	99.2	180.8	81.6	24.5 mil.[b]
Orange and grapefruit juice	8.8	27.5	18.7	21.5 mil.[c]
Total				123.3 mil.
EC-9				
Beef (new tariff line)	—	—	22.1	66.3 mil.[d]
Austria				
Beef	.7	1.4	.7	1.8 mil.[e]
Switzerland				
Beef	.7	5.1	4.4	11.8 mil.[f]
Grand Total				203.2 mil.

[a] Calculated at $2.50/lb.
[b] Calculated at 30¢/lb.
[c] Calculated at $1.15/lb.
[d] Calculated at $3.00/lb.
[e] Calculated at $2.75/lb.
[f] Calculated at $3.00/lb. for 1.5 million lbs. and $2.50/lb. for 2.9 million lbs.

tariff changes and the quota adjustments by Japan are $215 million. To this must be added the unknown but possibly large future value of new tariff bindings, especially on soybeans. Another positive point about this agreement is that the quota adjustments do, in fact, reflect changes in significant nontariff barriers. The precedent-setting value of these concessions should not be minimized despite their relatively small dollar values.

The European Community (EC-9)

The EC-9 concession covers about $960 million worth of 1976 agricultural trade. About $19 million involves a "free" tariff binding on peanut imports, and $8 million reflects a tariff reclassification agreement for some poultry items. The balance, about $933 million, involves trade affected by tariff cuts and a new arrangement for high-quality beef.

EC-9 tariff cuts. The tariff concessions by EC-9 span about thirty products totaling $867 million in 1976 trade value. Their contribution to expanded trade is shown in table 3 with full tariff cuts assumed. The totals show that trade values increase by an estimated $102 million or about 12% of the value of covered items. None of the key products in the CAP are involved substantively.

High-quality beef concession. A new tariff line for high-quality restaurant and hotel beef will cover an informally agreed upon import volume of 10,000 metric tons (22.1 million lbs.) or less. The traditional variable levy system will not apply to this line. At a per-unit trade value of $3.00 per pound, this EC-9 concession will approximate $66 million in new trade, table 4.

EC-9 summary. The EC-9 settlement shows an estimated $102 million tariff-related trade increase and $66 million in new beef trade for a total of $168 million. The new trade value of the tariff category reclassification in poultry is uncertain at this time as is the future value of the "free" peanut tariff binding.

Canada

Canada's agricultural trade concessions to the United States involve mainly the reduction and binding of existing tariffs. The 1976 trade coverage is $423 million, of which $413 million is accounted for by commodities for which tariffs were reduced. Almost $10 million reflects official binding of "currently applied" tariffs on prepared cereal foods. (These "currently applied" tariffs are approximately 40% lower than the official book rates.) Less than a million is accounted for by Canada's agreement to open the importation of canned turkey for "general licensing."

Table 3 shows estimated trade values of the proposed settlement with Canada. The total new trade value is estimated at $56 million. On the $413 million coverage base, this is a 13.6% trade gain strictly due to the tariff cuts.

Other Nations

The United States reached MTN tariff and access agreements with about thirty other nations or groups of nations acting together. These agreements cover tariff bindings and reductions as well as some adjustments in nontariff trade barriers. Their annual new trade value is $24 million.

Tariff bindings. Approximately sixty individual tariff bindings were achieved on products exported by the United States. Twenty nations offered these bindings with a total trade coverage of almost $450 million, 59% being concentrated in soybeans and soybean oil. They represent no new trade but do represent insurance against future duty increases.

Tariff reductions. Approximately ninety individual tariff reductions were achieved with eighteen nations on a wide variety of U.S. agricultural exports. These negotiated duty cuts vary from large to very small. The 1976 trade coverage of these tariff agreements is approximately $47 million. The estimated value of new trade generated by these tariff cuts taken together is only $9.0 million, table 3.

Nontariff barriers. About fifteen individual new agreements on nontariff trade barriers are in hand. They include quota increases, licensing procedure changes, and bindings on import-mixing regulations. These are important enough to warrant separate consideration.

U.S. Agricultural Import Concessions

There are two major categories of specific trade concessions offered by the United States. First and most important is an enlargement and rearrangement of Section 22 import quotas on cheese. The second is a wide variety of tariff reductions on agricultural imports ranging from wool to canned pineapple. In this section, estimates are presented for the dairy import concession and for as many of the others as feasible. Their total new trade value is calculated at $106 million.

Dairy imports. The proposed MTN agreement on dairy imports enlarges the quotas on foreign cheese, eliminates the current "price break" system, and brings all "price break" cheeses under the new quotas. If the new quota system had been in effect last year, approximately 15,000 metric tons of additional cheese could have been imported into the United States on an annual basis. This is the equivalent of 275–300 million additional pounds of milk on the domestic market, approximately 0.25% of total annual U.S. milk production. It also represents slightly less than 0.9% of total U.S. cheese production on an annual basis.

This potential increase in imports could depress milk prices by an estimated 5.4¢ per hundredweight (cwt) at the farm level (USDA 1975; Buxton and Fallert). Such a price decrease would happen only if nothing else changed and if cheddar cheese prices were more than 1¢ or 2¢ above support levels so that the downward adjustment actually could occur. If not, government purchases would prevent the price from falling. Taking the 1978 level of milk output as a basis, the cost of this trade concession to U.S. dairy farmers is $66 million. This is about 0.5% of the farm value of milk production in 1978.

Other MTN agricutural concessions. No other MTN concessions in agriculture approach the value of the cheese import quota agreement. For the most part these other concessions are tariff reductions across a wide spectrum of products. Those susceptible to analysis are shown in table 5.

The coconut oil concession involves elimination of the current duty of 1¢ per pound. Lamb tariffs are to be cut from 1.7¢ to 0.5¢ per pound. Tariffs on apparel wool are to be reduced by 60%. The canned pineapple tariff will go from 3% to 1% ad valorem. The tobacco concession involves tariff cuts on various cigars and cigar tobaccos. On canned beef, the duty cut is from 7.5% to 3.0% ad valorem. The barley concession reduces the tariff from 7.5¢ per bushel to 5.0¢.

The United States also agreed to cut tariffs on several products covered by the Meat Im-

Table 5. Value of Miscellaneous MTN Tariff Concessions Offered by the United States

Item	Import Value (1976)	New Import Value	Change
	--- ($ million) -----		(+)
Coconut oil	179	187	8
Lamb	21	29	8
Wool	54	60	6
Canned pineapple	68	73	5
Tobacco products	36	41	5
Cooked beef	68	73	5
Barley	53	56	3
Total			40

port Law of 1964 and Section 22 import quotas. Since the quotas themselves were not adjusted, estimates were not calculated for "new" trade. Items in this group include meat (mainly beef), butter, cream, and two specific staple lengths of cotton. Cheese tariffs will be cut 20%–25% as the new quota system is put into place.

Concluding Comments

In the Tokyo/Geneva Round, the United States placed high priority upon achieving improvements in agricultural trade through MTN agreements. As with previous rounds, major breakthroughs in protectionist agricultural trade policies were not obtained, even though the Tokyo/Geneva Round lasted five and one-half years. However, a series of agreements were achieved that should modestly enhance the highly favorable balance of trade exhibited by U.S. agriculture. Changes in some nontariff trade barriers achieved in the Tokyo/Geneva Round may establish extremely valuable precedents for future trade negotiations. Moreover, tariffs on some important U.S. exports to major markets were bound against future increases. The consultative commodity agreements, the new behavioral codes, and the GATT framework changes also negotiated at the Tokyo/Geneva Round were not emphasized in this paper.

The three major packages negotiated with Japan, the European Economic Community (EC-9), and Canada will enhance annual U.S. agricultural exports by an estimated $215 million, $168 million, and $56 million, respectively. A series of agreements with some thirty additional nations will add $24 million for an overall total of $463 million annually. This is approximately 2.1% of the 1976 base trade figures used throughout the report and by the Office of the Special Trade Representative.

In addition, tariff bindings were obtained on products whose exports totaled $1,278 million in 1976. About 80% of this total is accounted for by a "free" binding on soybeans conceded by Japan and by other tariff bindings on soybeans and their products offered by five other nations.

On the agricultural import side, the United States has made a significant quota adjustment for dairy products (cheese) and a series of tariff reductions for other products. The value of these concessions in terms of increased agricultural imports is approximately $106 million annually. Thus, these concessions will increase agricultural imports by about 1.0% over the 1976 base trade figures.

The net change in overall agricultural trade due to the MTN agreements is an increase of $357 million in 1976 terms. A plausible estimate of this annual value in 1979 terms is about $400 million. Making a further adjustment for value added, this increase in trade corresponds to the annual value of sales of about 6,500 average-sized farms in the United States. No one can argue that the MTN was a bonanza for U.S. agriculture, but the results are not to be ignored either.

References

Buxton, B., and R. Fallert. *Impact of Dairy Product Imports on U.S. Milk Price.* Dep. Agr. Applied Econ. Staff Pap. P74-21, University of Minnesota, Oct. 1974.

European Communities. *The Agricultural Policy of the European Community.* Brussels: Statistics Office of the European Communities and the Directorate-General for Agriculture of the European Communities, 1976.

Golt, Sidney. *The GATT Negotiations 1973–79. The Closing Stage.* London: British North American Committee; Washington, D.C., National Planning Assoc., May 1978.

Hillman, Jimmye S. *Nontariff Agricultural Trade Barriers.* Lincoln: University of Nebraska Press, 1978.

Houck, James P. *MTN Studies (2): The Tokyo/Geneva Round; Its Relation to U.S. Agriculture.* CP 96-12, Committee on Finance, U.S. Senate, 96th Cong., 1st sess., June 1979.

Krauss, Melvin B. *The New Protectionism: The Welfare State and International Trade.* New York: New York University Press, 1978.

Livernash, Bob. "Congress Faces Hard Choices on Trade Liberalization Pact." *Congress. Quart.*, 14 Apr. 1979, pp. 678–83.

Middleton, Robert M. *Negotiating on Nontariff Distortions of Trade.* New York: St. Martin's Press, 1975.

Organization for Economic Cooperation and Development (OECD). *Agricultural Policy in Canada.* Paris: Agr. Pol. Rep. 1973.

———. *Agricultural Policy in the European Economic Community.* Paris: Agr. Pol. Rep. 1974a.

———. *Agricultural Policy in Japan.* Paris: Agr. Pol. Rep. 1974b.

Reidel, James. "Monitoring Trends in Protectionism." Washington, D.C.: World Bank, Development Policy Staff, Feb. 1979.

Sanderson, F. H. *Japan's Food Prospects and Policies.* Washington, D.C.: The Brookings Institution, 1978.

Schnittker, John. Statement before Subcommittee on Foreign Economic Policy, Joint Economic Committee of Congress. Mimeographed. Washington, D.C., 19 Mar. 1970.

Twigs, Joan. "MTN: Breaking the Nontariff Barrier." *Current Focus*. Washington, D.C.: League of Women Voters Pub. No. 546, Mar. 1979.

U.S. Congress, House of Representatives. *Background and Status of the Multilateral Trade Negotiations*. Washington, D.C.: 94th Cong., 1st sess., WMCP:94–5, 4 Feb. 1975.

U.S. Congress, Senate. *MTN Studies (1–5)*. Washington, D.C.: Committee on Finance, 96th Cong., 1st sess., CP 96–11, 12, 13, 14, 15, June 1979a.

U.S. Congress. *U.S. Trade Policy and the Tokyo Round of Multilateral Trade Negotiations*. Washington, D.C.: Congressional Budget Office background pap., Mar. 1979b.

U.S. Department of Agriculture. *The Impact of Dairy Imports on the U.S. Dairy Industry*. Washington, D.C.: ERS Agr. Econ. Rep. No. 278, Jan. 1975.

———. *Report on the Agricultural Trade Negotiations of the Kennedy Round*. Washington, D.C.: For. Agr. Serv. FAS–M–193, 1967.

———. *U.S. Agriculture and the Tokyo Round*. Mimeographed. Washington, D.C.: For. Agr. Serv., various fact sheets, 25 May 1979.

U.S. Department of State. *MTN: Multilateral Trade Negotiations*. Washington, D.C.: Bureau of Public Affairs. Current Policy 56 (revised), Apr. 1979.

Reprinted from
American Journal of Agricultural Economics
Vol. 61, No. 5, December 1979

The Dynamics of Supply: Retrospect and Prospect

Marc Nerlove

"... Per altra via, per altri porti
verrai a piaggia, non qui per
passare ..."

Dante Alighieri, *Inferno*, Canto III, vv. 91–92

It is, I think, safe to say that there are few topics of greater current interest than the agricultural production and food supply problems in low income and developing economies. In the preface to the proceedings of a recent conference on "Distortions of Agricultural Incentives," Schultz (1978) wrote:

> The biological constraints on potential food production have been substantially reduced by advances in agricultural research and by the availability of additional capital. But it has become increasingly evident that the adoption of the research contributions and efficient allocation of the additional capital are being seriously thwarted by the distortion of agricultural incentives. (vii)

I also concur in Schultz's belief that (1978)

> Farmers the world over, in dealing with costs, returns, and risks, are calculating economic agents. Within their small individual, allocative domain they are fine-tuning entrepreneurs, tuning so subtly that many experts fail to see how efficient they are. . . . (p. 4)

Often costs and returns which individual farmers confront are expressible in terms of market prices, although the risks they face are usually not so easily quantifiable. Whether such market forces, however, impinge directly and visibly on individual farm entrepreneurs, it will nonetheless be true, if we accept the presupposition of optimizing behavior, that shadow prices and opportunity costs are crucial determinants of agricultural supply. It follows that responses to changing "prices" for outputs and inputs, whether made visible by markets, must be a key element in our attempt to understand the agricultural production and food supply problems in low income and developing economies, as well as in the highly efficient and productive agricultural sectors of the developed and high income countries of the world

In what follows I examine what has been done on the problem of measuring agricultural supply response since the publication of my own work on the subject more than two decades ago (1956, 1958). Much of this work, that is available in English and done up to about 1976, has been exhaustively summarized by Askari and Cummings (1976, 1977), on whom I principally rely. Although many useful and interesting modifications have been made, particularly in applications to dynamically complex production processes, such as those for perennial crops and livestock, and to the study of agricultural supply response in developing economies, the adjustment and expectational models which were used in my own work remain basic in most of what has subsequently been done. In a lecture delivered in 1970 to the World Congress of the Econometric Society and later published (1972), I pointed out the ad hoc nature of most distributed lag formulations used in empirical

---

Kellogg 50th Anniversary Lecture.

Marc Nerlove is a professor in the Department of Economics at Northwestern University.

This lecture was written during Nerlove's tenure as a scholar-in-residence at the Bellagio Study and Conference Center of the Rockefeller Foundation and while a Fellow of the John Simon Guggenheim Memorial Foundation. The author is indebted to Rockefeller and Guggenheim Foundations for the environment in which, and the werewithal with which, to pursue this endeavor. Neither foundation is, of course, responsible for the opinions expressed.

The author also gratefully acknowledges many helpful conversations with colleagues at the Bellagio Center, John W. Mellor, and Uma Lele. The discussion of perennial crops at the end of sect. 3 draws on correspondence with M. J. Hartley of the World Bank. The author's deepest intellectual debt is to T. W. Schultz and D. Gale Johnson who have, over the years since his initial work on the subject, continued to shape and influence his ideas concerning agricultural supply response. The author's errors are his own. He also should like to take this opportunity to thank B. F. Stanton and the Executive Board of the American Agricultural Economics Association for the honor and opportunity offered to him in their invitation to present this lecture.

econometrics, including those resulting from the models used in my work on supply, and entered a plea for the development and implementation of "econometrically relevant" dynamic models of optimizing behavior.

It is easiest to see the need for such dynamic models in the case of production processes which are biologically of relatively long duration, such as those for perennials and livestock; moreover, the biological structure can be used, in the first instance disregarding the other durable inputs, to determine the dynamic structure (Carvalho 1972; Nerlove, Grether, Carvalho 1979, pp. 327–53). It should be emphasized, however, that the same arguments apply to any processes involving durable inputs, including structures, implements, and improvements to land, and it is less easy to develop appropriate models which capture essential dynamic features in these cases. Following a brief review of what has been done on the problem of measuring agricultural supply response, I turn to the question of how to make distributed lag formulations less ad hoc, in the sense of being based on dynamic optimizing behavior, specifically within the context of livestock and perennials.

This discussion does not fully resolve the dynamic problems involved in studying agricultural supply response in the context of a developed economy; moreover it does not touch at all on the essential dynamics of supply response in developing economies. Below, I suggest that to understand these dynamics it is essential to consider the causes of changes in the agricultural sector, the complex of forces set in motion by technological improvement, public investment in infrastructure and the development of markets, and the differential abilities of economic agents to deal with the resulting disequilibria. In most developing economies the agricultural sector is so large and so central to the whole process of economic growth and demographic change, that supply response cannot be treated as an isolated phenomenon. Moreover, in these economies, markets, at least as we know them in developed economies, may be poorly organized or may not exist at all; it follows that the relevant "prices" motivating producer behavior may be difficult, or impossible, to observe directly. Many of the trade-offs in the allocation of resources may take place within individual farm households or between these households and relatively isolated labor or product markets. Traditional methods of aggregative time-series analysis of supply cannot even begin to capture these kinds of responses.

Finally, I attempt to draw some general conclusions about the data and analytical methods needed to push forward the frontiers of our knowledge of the dynamics of supply in a complex and developing world.

Retrospect

In their exhaustive survey of the English language literature on agricultural supply analysis, Askari and Cummings (1976), take note of more than 600 estimates of supply response to price. The studies surveyed deal, for the most part, with annual food crops in developed countries or in areas for which reasonably good price date exist, e.g., South and East Asia. A number of studies surveyed cover nonfood annual crops such as fibers and tobacco, semiperennials such as sugar, perennials such as cocoa, coffee, tea, and rubber, and livestock and livestock products. The last group are all for developed countries for which livestock data are relatively complete. Although many of the studies, particularly those dealing with perennials, introduce important modifications and extensions, the basic model employed in most is the formulation I advanced some years ago (1956, 1958). Stripped to its essentials, this model for an annual crop consists of three equations:

$$A_t - A_{t-1} = \gamma(A^*_t - A_{t-1}), \tag{1}$$

$$P^*_t - P^*_{t-1} = \beta(P_{t-1} - P^*_{t-1}), \tag{2}$$

$$A^*_t = a_0 + a_1 P^*_t + a_2 Z_t + U_t, \tag{3}$$

where A_t is actual area under cultivation in t; P_t, actual price of the crop per unit in t; A^*_t, "desired" or equilibrium area to be under cultivation in t; p^*_t, "expected normal" price in t for subsequent future periods; Z_t, other observed, presumably exogenous, factors; u_t, unobserved, "latent" factors affecting area under cultivation in t; and β and γ are "coefficients of expectation and adjustment" reflecting the responses of expectations to observed prices and observed areas under cultivation to changes in equilibrium areas.

The statistical problems of estimating a model such as (1)–(3), particularly of identifying relevant observed exogenous variables, not subject to expectational lags, and problems due to serially correlated disturbances

are well-known. In addition, the use of area cultivated, one input in the production process to represent planned output, the problem of choosing the relevant price or prices, and other issues of specification, such as the inclusion of expected yields, weather conditions, and price and yield variances to take account of elements of risk, have been widely discussed in the literature.

Important modifications of the basic model have been made in connection with its application to cereals and basic food crops in developing countries. These commodities are at least partly consumed on the farms on which they are grown so that a key question becomes the response of marketed surplus to price. Among the studies of particular interest are those of Raj Krishna (1963, 1965) for rice and wheat in the Punjab, of Behrman (1966, 1968) for rice and other food crops in Thailand, and of Nowshirvani (1968) for a number of food grains in various regions of India. An important point made in these studies is the need to take into account the income elasticity of consumption within the farm household. Nowshirvani (1968, 1971) shows also, in a model involving both food grains and strictly cash crops and a farm-household utility function expressing risk aversion, that stabilization of food prices may sometimes lead to a reduction in supply. Askari and Cummings (1976, pp. 52–162) discuss a large number of such studies, including some for food grains in developed economies. Some of the investigations also introduced prices of other factors, size of farm, and variables related to irrigation, tenancy status, health, and so forth.

Using their collection of elasticities, Askari and Cummings (1976, pp. 342–82) attempt to get at some of the factors which might explain variations in supply response to price across regions and commodities, finding that higher income levels and larger farm sizes, availability of irrigation and reduced yield variability, greater literacy levels, and ownership as opposed to tenant-status, all increase responsiveness to variation in output prices.

I return below to some of the problems I see in these applications of the basic supply response model on a crop-by-crop basis in developing economies in which substantial changes are occurring in the availability of new varieties and of inputs other than land and labor, and in which major improvements in infrastructure are taking place.

Applications of the basic model have also been made to various nonfood annual crops such as cotton, jute, and tobacco. (See Askari and Cummings 1976, pp. 163–218.) Perhaps the most interesting applications and modifications of the basic model, however, are in connection with perennial crops. Such crops, once planted, yield a flow of output, continuously or discretely, over a period of years. Many are tree crops, which must mature several years after planting before any output is forthcoming, and for which thereafter yields are dependent upon the age of the tree and may also depend upon other inputs. In the earliest studies of perennials, the vintage or effect of the age distribution of the stock has been noted, and the decisions to plant new stock or cull older trees have been viewed as investment decisions under uncertainty, at least with respect to product prices, if not also input prices or prices of crops which might compete for land or labor. Moreover, the decision to harvest from a given stock at any particular time may also reflect opportunity costs or labor costs during and immediately surrounding the harvest period.

A number of difficulties arise in connection with the study of many perennial crops in developing countries. First, except in rare instances, continuous information over time is lacking on new plantings and current age structure, although such information may be available irregularly. This means that a key variable in the analysis, namely the age distribution of the stock, may have to be determined within the supply model itself, i.e., inferred from a time series of actual output (Hartley). Second, government intervention in the marketing of perennial crops is widespread. One effect, for example, in the case of Ghanaian cocoa, is to lead to smuggling of significant amounts of output. The existence of marketing boards which create substantial spreads between prices paid to producers and the prices at which the crop is sold and which hold large stocks of the commodity in question may also lead to significant problems in formulating appropriate models of expectation formation (Bacha). Third, as indicated above, there is frequently an imperfect relation between output and the stock of the perennial, since the existence of alternative uses of other inputs and variable prices and yields makes the decision not to harvest, or to harvest only partially, a viable option. Depletion of the stock may vary not only because of culling, but also because of the differential effects of

weather and disease. Finally, technical change in the form of improved varieties introduces a new element of uncertainty especially in view of the long-time horizon.

Notable among the studies of perennials are those of Bateman (1965a, b, 1968), Behrman (1968b) and Stern (1965a) on Ghanaian cocoa; Behrman (1969), and Stern (1965b) and Chan (1967) on Malaysian rubber; and by Arak (1967, 1968, 1969) and Bacha on coffee. Most of these studies utilize stock adjustment models and price expectation formation models similar to (1) and (2) above, but adapted to the long lags involved between planting and the emergence of output. Stocks are inferred from a sequence of outputs so that the models quickly become rather complicated, especially when a competitive relation between several perennial crops is considered. Wickens and Greenfield have been critical of previous investigations for neglecting the important distinction between investment and harvesting decisions and have attempted to estimate a more complex model for Brazilian coffee. The most elegant work to date on perennials is that of French and Matthews on U.S. asparagus (a perennial crop with a bearing life of ten to fifteen years). Their model distinguishes between the quantity of produce and bearing acreage, new plant, and removals of old plants. It must be recognized, however, that the data available are greatly superior for this crop than for most perennials important in developing countries.

Livestock and livestock products have been studied mainly for developed economies. The most common approach has been to employ some variant of the adjustment model (1) applied to a measure of "capital stock." In the case of milk, for example, in which production is continuous, seasonal factors have been introduced. Various combinations of current and lagged prices are used but rarely has much specific attention been devoted to the problem of expectations formation. A large number of studies are summarized by Askari and Cummings (1976, pp. 299–341) notable among which are Halvorson, Gardner, and Gardner and Walker on milk, Dean and Heady on hogs, and Jones, and Jarvis (1969, 1974) on beef. My own work with Carvalho and Grether, and Carvalho is discussed below since it is of a rather different character than the aforementioned studies.

While Jarvis (1969, 1974) did attempt to estimate a specifically capital-theoretic model, he was handicapped by lack of data on births and had to reconstruct them from herd size, slaughter, and deaths. Mascolo had similar problems in his study of the Brazilian cattle industry in which, however, he attempts to follow the lines of Nerlove, Grether, and Carvalho; and Carvalho.

Despite the greater complexity of perennials and livestock in a dynamic sense, there does not appear to have been an attempt to go beyond an essentially static formulation of the demand for the stock from which output is produced. Dynamic considerations are introduced through fixed, biologically determined lags together with ad hoc stock adjustment and/or price expectation formation models, such as (1) and (2), originally used in the study of animal crops. In the next section, I address myself to this issue and show how more econometrically relevant dynamic models can be constructed for livestock and perennials under certain simplifying assumptions. Many of the same arguments can be made with respect to annual crops if long-lived capital equipment, structures, or land improvements are significantly involved in production. In the section following the next, I take up the far more serious difficulties encountered in the study of agricultural supply response within the kind of dynamic setting encountered in a developing economy in which the agricultural sector is concurrently being transformed from traditional to modern.

Distributed Lag Models of Supply Response Based on Dynamic Optimization Behavior

The basic supply response model discussed in the preceding section incorporates dynamic elements in two different ways: First, a distinction is made between a long-run equilibrium position toward which producers are assumed to be moving and their current position. The former is determined on the basis of a static theory of optimization, in this case the standard microeconomic theory of the firm and the assumption that the exogenous variables of the problem, in this case mainly prices, are given once and for all. Elsewhere (1972, p. 225), I have called this the assumption of static, or stationary, expectations. The important point is that whatever these expectations are and however they are formed, the concept of a long-run equilibrium solution to the optimization problem is well-defined only if it can be assumed that the values of the

exogenous variables expected in the future are unchanging; it does not matter if the constant future value of each variable differs from its current value, as indeed it plausibly will. Having a well-defined notion of a long-run equilibrium position then permits us to examine the question of why producers are currently at a position different from that equilibrium. At this point the discussion usually becomes vague; one can argue in various ways (Nerlove 1972, pp. 228–31), but perhaps the most common approach is through the introduction of adjustment costs. Rarely, however, are models explicitly introducing these costs formulated or the rationale for such costs carefully examined. (The literature up to about 1970 is surveyed and two models of investment behavior incorporating both separable and nonseparable adjustment costs are discussed in Nerlove 1972, pp. 231–41; see also Nerlove, Grether, Carvalho, pp. 317–20.) The dynamic element in the basic supply response models is introduced at this point without a formal theory by the simple ad hoc assumption that each period, if we are dealing with discrete time, a fraction of the difference between the current position and the long-run equilibrium is eliminated, i.e., equation (1) above.

In the next section, I argue that the matter of adjustment to equilibrium, if indeed equilibrium is an appropriate concept, in the agricultural sector of a developing economy in the process of transformation is far too important to be treated in such an ad hoc manner. The simple adjustment process assumed in the basic supply response model is undoubtedly also inadequate to describe the dynamics of supply in a developed economy in which technical change is occurring at a rapid, if uneven, rate, and in which the demands for agricultural outputs and the supplies of inputs are subject to substantial shifts. In the case of perennials and livestock, however, there is no need to introduce an ad hoc adjustment model since the intrinsic biology of the production process already provides most of the essential dynamic structure.

The second way in which dynamic elements are incorporated in the basic supply response model is through a description of expectation formation, e.g., the adaptive expectations generated by equation (2), in which expected "normal" prices are revised each period in proportion to the difference between last period's observed price and the previous expectation. Above, I argued that static, or stationary, expectations are necessary to make the concept of a long-run equilibrium meaningful; the adaptive expectations model does not violate this principle, since it is not solely next period's price to which P^*_t refers but "normal" price, i.e., an average price expected to prevail in all future periods. The argument that farmers rationally should respond, not to the best forecast they can make of next period's price, but rather to some average or "normal" level, rests intuitively on the idea that there are costs of adjustment. However, virtually any plausible model one can construct, with costs of rapid adjustment of, say, a durable factor of production, will generally involve response to prices in many future periods although the weights which attach to the more distant future will usually be less than to the near future. Moreover, unless the optimization problem has a specific form, it will generally be nonoptimal to behave as if one were responding to a point estimate of each future value. (Theil; see also the discussion in Nerlove, Grether, Carvalho, pp. 334–37.) When the optimization problem is of this specific form, however, we say that there exist certainty equivalents to the uncertain future values of the variables to which response is occurring. Such certainty equivalents are the conditional expectations of the variables to which they refer; they are minimum-mean-square-error forecasts based on the information available up to the time the forecast is made and taking into account the structure of the system generating the data. Muth (1961) has termed such forecasts "rational expectations."

Apart from whether they are certainty equivalents, when are adaptive expectations rational in the sense of being conditional expectations? Muth (1960) provided an early answer to this question which I later generalized (1967). For a simple unobserved-components model of the time series of, say, prices, it can be shown that the minimum-mean-square-error forecast for next period and for every future period is the same exponentially weighted moving average of past values (Nerlove, Grether, Carvalho, pp. 320–23). In general, several endogenous variables, such as prices and quantities, will be determined by a series of structural relationships, such as supply and demand functions, reflecting the behavior and expectations of different groups of economic agents, such as farmers and consumers. In this case, the behavior of farmers who respond to

conditional expectations of an endogenous variable, such as price which is determined in the market by the equilibrium of supply and demand, cannot be characterized so simply; generally the distributed lag relationships will contain parameters of the structural system, as well as parameters reflecting the serial properties of the structural disturbances. These relationships among the structural parameters and the characterizations of the conditional expectations of endogenous variables imply certain restrictions on the form of the minimum-mean-square-error forecasts of future variables.

Time-series modeling and forecasting is a complex subject of considerable current interest. Much of the recent literature leads away from the structural equation approach of traditional econometrics. Single and multiple time-series models are formulated in terms of fairly simple moving-average autoregressive processes (ARMA processes) involving relatively few parameters (Nerlove, Grether, Carvalho, pp. 103–46). If the exogenous variables of a structural system are expressible in terms of ARMA processes, or if their effects can be removed prior to analysis, then under certain conditions, the final form of a structural equation system can be reduced to one in which each endogenous variable is expressible in terms of an ARMA process, which, however, may be relatively complex and involve restrictions across the various representations (Zellner and Palm; Wallis). A simple supply and demand example is contained in my recent book with Grether and Carvalho (pp. 302–308). There, we call conditional expectations, or minimum-mean-square-error forecasts, based on univariate or multivariate time-series analysis neglecting such restrictions as may arise from the simultaneous determination of several endogenous variables with a structural system, quasirational expectations. Such forecasts are easy to obtain by formulating and estimating relatively simple univariate or multivariate time-series models (a univariate model being one in which only information on the past of the series itself is used, whereas a multivariate model allows the information contained in the past values of related series to be used in estimation and forecasting). If we assume the economic agents, whose behavior we are attempting to describe, are aware of the underlying structure, quasi-rational expectations offer an approximation to fully rational expectations and a far less arbitrary, less ad hoc, approach to expectation formation than the adaptive expectations used in the basic supply response model. In general, however, such forecasts will not be the same for different future periods, i.e., they will not represent static or stationary expectations in the sense defined above.

If, then, we reject the adaptive expectations model, and, with it, the proposition that farmers respond to the expectation of some average of prices in all future periods, we must also dispense with the notion that farmers are adjusting toward a well-defined, long-run equilibrium in each period, because this equilibrium is well-defined only for stationary expectations. I hasten to add that this does not mean stationary equilibria are totally irrelevant in the analysis of agricultural supply response; indeed, a long-run equilibrium with stationary expectations may characterize traditional agriculture in countries prior to development and may approximate the final position of farmers after response to a one-time major shock. This, however, is not dynamics but comparative statics. As I have argued elsewhere (1972), an econometrically relevant dynamic theory would characterize response paths of economic agents who are optimizing their behavior under dynamic conditions and forming expectations of the future on the basis of all information available to them. Such a theory would not, in general, involve the notion of a long-run equilibrium toward which adjustment is being made nor simple forms of stationary expectations. Formulation of models based on this principle is not an easy task, nor may you think it worth the effort when you have seen the example of a recent attempt to model the U.S. cattle industry, to a brief sketch of which I now turn.

A simplified model of the U.S. cattle industry was developed and estimated by Carvalho; a modified version of this model is presented and reestimated in the final chapter of Nerlove, Grether, Carvalho pp. 327–53). Neither the market for feed nor the milk sector are considered explicitly, although these markets impinge on the cattle market through the costs of inputs and the prices of beef, especially utility beef and veal, which come in large part from the dairy sector. The reproductive herd consists of cows, heifers older than eighteen months, and bulls. The latter are neglected. We assume the production of young animals to be proportional to the size of the reproductive herd and than one-half of these are males

which are castrated to become steers. The optimal decision concerning heifers is whether (*a*) to slaughter, (*b*) to place on feed, (*c*) to add to the reproductive herd, or (*d*) to breed, in which case the heifer becomes a cow by definition. In the case of a steer, however, there are only two choices: (*a*) to slaughter now, or (*b*) to keep on feed. Cows may be (*a*) kept in the reproductive herd, (*b*) placed on feed, or (*c*) sold for slaughter. Additions to the stock of cows occur through the addition of newly bred heifers; subtractions occur through the sale of cows for slaughter or natural mortality. (The latter is small and we neglect it.) Because there are biologically determined lags between the time a cow can be bred and the time her offspring can be slaughtered, added to the reproductive herd, or placed on feed, and because there are intrinsic costs of aging which make it unprofitable to hold an animal forever, there is a natural dynamic structure in this problem: What the producer does now will affect the constraints under which he operates for some time into the future, but not forever; therefore his current decisions must reflect what he now expects conditions will be in relevant future periods; but, because the lags involved are finite and animals cannot be held forever, the indefinite future does not matter. The same dynamic characteristics also apply in the case of perennial crops. When long-lived capital is involved in a production process, then, in principle, the distant future is involved in current decision making, but, if the future is discounted and if capital depreciates, in practice only the near future will matter.

In the empirical example reported in Nerlove, Grether, Carvalho (pp. 338–53), we choose calendar quarters as our observational unit. Specifically: the gestation period is nine months or three quarters; we assume births are proportional to the stock of cows in the reproductive herd and that one-half of all births are male; bulls are neglected and we assume that an animal is not considered as added to the stock of heifers or steers on feed nor to the reproductive herd until nine more months have passed. The decision variables each period are numbers of (*a*) steers to be sold, (*b*) heifers to be sold, (*c*) heifers to be bred, i.e., placed in the reproductive herd, and (*d*) cows from the reproductive herd to be sold for slaughter. Given prices for steers, heifers, and cows, gross revenues are a linear function of the numbers sold in each category provided we assume, as a first approximation, that price is independent of age; however, in our formulation we also introduced quadratic terms reflecting "aging costs" for each of the three categories, so that longer retention of an animal results in a lower "net" receipt. The decision variables are conditioned by the stocks of steers and heifers on feed, by the size of the reproductive herd, and by births nine months ago. The decision variables and conditional variables are constrained by a set of linear identities expressing our assumptions about the nature of the lags involved. In addition to aging costs, we assume quadratic costs for maintaining animals on feed or in the reproductive herd, different for steers, heifers, and cows, and an additional quadratic cost for maintaining calves each period prior to the time at which they can be allocated to one of the stocks or slaughtered. We also assume a "breeding" cost over and above the cost of maintaining a cow in the reproductive herd. Feeding costs plus aging costs are assumed to reflect variations with age both in the ability of an animal to transform feed into flesh and the decreasing value, *ceteris paribus*, of older animals. We assume that the cattle producer makes his choice so as to maximize the expected discounted present value of future net revenues from sales of steers, heifers, and cows to some finite, but distant horizon (retirement), subject to uncertain future sales prices but known constant aging, feeding, breeding, and maintenance costs and a constant rate of discount. Because of the structure of the problem, the finiteness of the horizon, in fact, turns out not to matter.

Because our objective function is quadratic in the decision variables and the uncertain prices and since all the constraints among these variables are linear (see Nerlove, Grether, Carvalho, pp. 335–37), there exist certainly equivalents for the unknown future prices, namely their conditional expectations at decision time, given past values of these variables, which, in the present problem, we assume are all the information at the disposal of the cattle producer. (In a more complete and complex model we might also wish to consider demands for various types of cattle as well as the market for feed and other inputs; in this case the distinction between rational and quasirational expectations would become important.) The existence of certainty equivalents means we can replace prices by their conditional expectations and proceed as if we were dealing with a problem of decision mak-

ing under certainty. The problem as formulated is now a relatively simple dynamic programming problem which, if numerically specified, could be solved by standard methods. However, as we have set the problem up, it is not numerically specified: the discount rate and aging, feeding, and maintenance costs are all behavioral or technological parameters, or some combination thereof, to be determined by estimating the model. What equations do we estimate? Presumably one each for each of the four decifion variables: The stocks of steers and heifers, the size of the reproductive herd, and new gross investment, i.e., the number of heifers added to the reproductive herd. Alternatively, equations determining any four equivalent variables related to the foregoing by the identities referred to above may be estimated. To find these equations, we must solve the dynamic programming problem algebraically in the usual recursive manner, backwards from the end of the horizon; the solution will generally differ depending on the number of periods to go to the end of the horizon; however, because of the nature of the lags involved, the solutions "stabilize" after a certain number of periods back. The number of periods differ for the different variables: It is only one quarter for steers, but five periods for heifers and additions to the reproductive herd, and four periods for cows. (See Nerlove, Grether, Carvalho, pp. 345–66, for an intuitive explanation.) When we say the solution stabilizes we mean that it is the same after, say, six periods as it is after five. A stable solution equation thus characterizes current producer behavior and provides a basis for estimation.

The characteristics of the stable solutions are as follows: The "own-demand for the stock of steers" depends upon the current price of steers in relation to the price expected next period and the size of the reproductive herd four periods ago. The "own-demand for the stock of heifers" depends on the current price of heifers in relation to the expected prices, one, two, five, six, and seven periods from now, the current price of cows in relation to the expected prices one through four periods from now, the expected prices of steers five, six, and seven periods from now, and the current and past four values of the size of the reproductive herd. Similarly, gross additions to the reproductive herd and the own-demand for the stock of cows depend on the current and expected future prices of heifers and cows, and the expected future prices of steers, and certain past stock variables. If we now formulate time-series models, in principle multivariate but possibly univariate, in order to obtain quasi-rational expectations as minimum-mean-square-error forecasts, the latter may now be substituted for the unknown conditional expectations of future prices. In this way, implicit distributed lag relationships are obtained; however, it should be emphasized that the behavioral relationships deduced in this manner do not explicitly involve any distributed lags. If the exogenous variables which drive the system, in this case the prices of steers, heifers, and cows were suddenly to become fixed at certain levels and thereby cease to follow the time-series models we had estimated for them, but cattle producers, implausibly, continued to assume that they did, the system would proceed over time to an equilibrium solution in which all variables remained unchanged forevermore. The same equilibrium would be reached, although the path to it would be different, if the same levels of prices were announced and believed with certainty. But this equilibrium is only implicit in the dynamic structure; it does not, in any sense, correspond to a long-run equilibrium position which is continually changing and toward which cattle producers are continually adjusting.

Although it is undoubtedly grossly oversimplified as a model of U.S. cattle production, we have estimated the model partially for the period 1944–69, using quarterly data. The results are reported in Carvalho and modified results in Nerlove, Grether, Carvalho (pp. 348–53). The reader is referred there for the empirical detail. My discussion here serves primarily to illustrate how econometrically relevant dynamic models of behavior can be constructed on the basis of optimizing behavior without recourse to the many arbitrary or ad hoc assumptions. Some of the latter must, of necessity, remain in any practical formulation, the most crucial of these being the assumptions necessary to obtain a problem in which relatively simple certainty equivalents exist.

In the absence of substantial technical change and/or rapid developments in intrastructure or markets, such as frequently characterize agriculture in developing countries, perennial crops are also susceptible to analyses similar to the one described above for livestock, but certain features of perennials

make the existence of relatively simple certainty equivalents doubtful.

Both because of the longer time horizon involved and a number of other characteristics, the analysis of supply response for perennial crops is likely to be more difficult than for livestock. First, the decision to plant such a crop is normally made far in advance of the expectation of any output. Even after output is forthcoming, the yield typically varies over the lifetime of the plant reaching a peak some years after initial output, maintaining a roughly constant level for a number of years, and then beginning a slow decline to eventually uneconomic levels. The pattern of yield may be varied somewhat by other inputs, but more importantly by choice of variety. During the initial phase of no output, and sometimes even beyond this period, the perennial may be interplanted with other crops. Second, whereas in the case of annuals the decision to harvest or not usually represents an insignificant aspect of supply response (but see Nerlove, 1958, pp. 112–21), harvesting costs typically represents a major part of the costs of production in the case of a perennial, so that knowledge of the age-distribution and yield profile of the existing stock of plants provides only an upper bound to potential output. Third, the stock of plants may be depleted over time not only by deliberate action of the producer to cull unproductive plants in the older age groups, to replant or replace existing plants with higher yielding varieties, or to plant alternative crops, but also by the differential effects of weather and disease. One cannot deduce the age distribution of the stock from a knowledge of past plantings alone. Moreover, the effects of poor weather or disease upon yields may be spread over a number of years.

As in the case of livestock, it is possible to formulate a dynamic programming model which can take into account the main features of perennial production. Apart from data limitations, which are typically very serious in the case of most perennials (Hartley), the chief difficulties appear to be the nonlinear constraint introduced by the bounding of harvested output by potential output and the additional uncertainty, beyond the uncertainty of future prices and costs, of yields due to weather and disease, but, more important, also as to the introduction of new plant material with highers yields. For example, in the case of rubber, research in Malaysia on the agronomy of natural rubber in the past twenty-five years has led to a more than threefold increase in commercial yields as new clonal materials have replaced previously unselected seedlings or inferior stock. I will return to the question of how new technology affects the dynamics of supply in the next section, but note here that its possibly discontinuous nature and uncertainty regarding when a new variety or new material may be available introduces a whole new dimension in the case of a long-lived perennial which is not present in the case of an annual crop. Unless harvests are normally well below potential always, a very implausible circumstance since one could not then explain why so much of the crop had been planted in the first place, the nonlinear boundary condition in itself would preclude the formulation of a dynamic optimization model having single-valued certainty equivalents. Even approximate certainty equivalents would be ruled out in this case (Malinvaud). The discontinuous nature and uncertain timing of technological change and the effects of weather and disease on yields would also seem to rule out single-valued certainty equivalents. Without such certainty equivalents, the dynamic programming model formulated and solved as if future prices, costs, and yields were known with certainty no longer represents a structure into which we can introduce quasi-rational or rational expectations based on time series of past prices, costs, and yields. No doubt, as additional work on perennials is undertaken, these issues will be resolved initially in an ad hoc manner with different analysts concentrating on different aspects of the problem.

Supply Response during Agricultural Transformation

In *Transforming Traditional Agriculture*, Schultz argued that farmers in traditional agricultural settings, while they may differ for reasons of schooling, health, and experience in their ability to perceive, interpret, and respond to new events as these impinge on their farm enterprises, do in fact allocate the limited resources at their disposal in a highly efficient manner. But within a traditional agricultural setting few adjustments are required and those which do occur are typically not large.

One can imagine an agricultural sector in which no changes in technology, infrastruc-

ture, markets, and so forth, have occurred for a long time. Under such "stationary" conditions, farmers may be poor, uneducated, and slow to perceive or respond to change. They may, nonetheless, be in virtually perfect adjustment to their environment and attain an efficient allocation of resources. In the case of a largely subsistence agriculture there may be few price signals to which to respond. Efficient allocation of resources largely consists then of proper allocation of time, land, and whatever limited physical capital exists in various household activities which include, not only farming, but other types of household production and consumption, the rearing of children, and such limited gross investment in human and physical capital as may be necessary to maintain existing stocks. If farmers have limited needs for goods they themselves cannot produce and limited opportunities for off-farm employment, markets and the infrastructure of communications and transport may be poorly developed or virtually nonexistent. In this case, one can learn very little about potential supply response to price or other changes by observing past behavior. One might infer little supply response to prices observed in central markets, for example, simply because such prices are largely irrelevant to the allocation problems which these farm households resolve.

Even when farmers sell a substantial fraction of their output of certain crops and buy other goods they need, fluctuations in market prices may induce little response simply because such changes are due to weather or other temporary factors which have little long-term significance for the allocative decisions being made.

Schultz (1975) puts the matter well and succinctly:

> Farm people who have lived for generations with essentially the same resources tend to approximate the economic equilibrium of the stationary state. When the productive arts remain virtually constant over many years farm people know from long experience what their own effort can get out of the land and equipment. In allocating the resources at their disposal, in choosing a combination of crops, in deciding on how and when to cultivate, plant, water, and harvest, and with what combination of tools to use with draft animals and simple field equipment—these choices all embody a fine regard for marginal costs and returns. These farm people also know from experience the value of their household production possibilities; in allocating their own time along with material goods within the domain of the household, they too are finely attuned to marginal costs and returns. Furthermore, children acquire the skills that are worthwhile from their parents as children have for generations under circumstances where formal schooling has little economic value. (pp. 831–2)

It is doubtful whether such a stationary state now exists or has ever existed, although it may have been approximated in certain times and places (a point made very clearly by Schultz, 1964). In modern agriculture, or in an agricultural sector in the course of modernization, constant changes are occurring. These changes are typically large, frequently discontinuous, and require major reallocation of resources both within the agricultural sector and between agriculture and the rest of the economy. Moreover, more often than not, these changes are not reflected in "visible" prices, although in market-oriented economies major shifts in the demand for various agricultural commodities or in the supply of inputs used in agricultural production do take the form of price changes. In the supply response studies discussed earlier in this paper, and, indeed, in my discussion of models of response based on dynamic optimization, I tacitly assumed that "visible" prices convey all of the information to which farmers find it necessary to respond. This is certainly not true even in recent times in a highly developed economy such as we have in the United States.

In the last fifty years we have experienced two major changes in U.S. agriculture, as well as, of course, a continuing sequence of lesser changes due to shifts in demand and supply and ongoing agricultural research. The first of these was the development and spread of hybrid corn, so well documented by Griliches. While it may be true that the differential spread of hybrid corn in the U.S. can be explained in terms of differing costs and returns and farmers' perceptions of these differences, such a formulation is not particularly useful in understanding the complex of forces related to the supply of research and discovery which brought about the change and which governed its rate of spread. On the other hand, the second major change, the remarkable fall in the cost of nitrogen fertilizer, which took place in the 1950s and early 1960s and which resulted in a significant increase in the optimal amount of such fertilizer applied to a variety of crops, was essentially a price phenomenon. Yet, as I think is shown by the studies of Huffman (1972, 1974, 1977), the changes which took place cannot be explained dynamically solely

in terms of relative prices. There is virtually nothing in the production process for corn, for example, which would have prevented an almost instantaneous complete adjustment, yet the adjustment did take time and the speed with which it occurred varied substantially in different parts of the Corn Belt. Using county data for the period 1959–64, during which prices of nitrogen relative to corn fell about 25%, Huffman computes a partial adjustment coefficient showing actual changes during the five-year period as a fraction of the changes by county necessary to achieve an optimum as determined from a production function for corn estimates from agronomic data. His major finding is that the speed of adjustment varies systematically across counties with respect to average levels of extension services provided, farmers' education, and farm size. One could not have predicted such results on the basis of the type of dynamic model discussed in the preceding section of this paper. If the production function is shifting and not completely known by producers, processing and dissemination of information and its incorporation into the optimization process constitute a more important part of the dynamics of supply than the issues we have raised thus far.

Two additional points are worth making in this connection: The research process, especially in the United States, has become institutionalized to such a degree that it and farmers' continuing responses to the wide range of new opportunities constantly opening up to them have become a central characteristic of the dynamics of supply in modern agriculture. Second, developments in the industries supplying inputs to agriculture are not unrelated to other types of research, such as the continued development of new varieties of plants which use fertilizer and water more effectively or lend themselves more readily to mechanized cultivation and/or harvesting. The impact of the fall in fertilizer prices would have been far less without the hybrid varieties, and, conversely, the profitability of the new varieties would have been less great with higher fertilizer prices.

What lessons does the U.S. experience hold for understanding agricultural supply response in developing countries today? I return to the theme on which I touched at the very beginning of this paper: To understand the essential dynamics of supply in developing economies, we must consider the causes of change in the agricultural sector, the complex of forces set in motion by technological improvement, public investment in infrastructure and public health, the development of markets, and the differential abilities of economic agents to deal with disequilibria. From what I know of agriculture in developing countries, I would suggest several major sources of change in agriculture during modernization:

(*a*) As investments are made in better communications, transportation, and other types of infrastructure, there are greater opportunities for markets of all kinds to develop. In consequence, price signals are likely to become more important, not less, as farm people become less isolated. Moreover, the markets and prices which are important in understanding the dynamics of supply are not limited to product markets and prices. Clearly, inputs such as fertilizer, farm implememts, herbicides and insecticides, better seeds, and so forth, are increasingly purchased and used. But labor markets also develop more fully and farm people begin to respond to opportunities for off-farm employment, part-time, seasonal, and permanent. The impact of changes in the labor market on supply response may be at least as great as the impact of changing product prices.

(*b*) The process of technical change in agriculture accelerates and becomes increasingly institutionalized and indigenous. Improvements in varieties of plants and animals and in the other inputs which are necessary to make these varieties more productive become an increasing source of supply response. The dynamics of supply under these circumstances can be understood only by understanding the determinants and manner of adoption of new agricultural technology and how it comes to be produced on a continuing basis. The so-called "green revolution," the rapid adoption of new, highly productive wheat varieties by the small, financially poor, uneducated farmers of the Punjab is perhaps somewhat misleading in this connection. To be sure, this event, and others like it the world over, and the development of international agricultural research centers, have had a major impact on supply. Continued change, however, is likely to rest more on a series of smaller, less dramatic developments, the perception of which will require improvements in the abilities of farm people to adapt to maintained disequilibria. Improvements in rural educational facilities, especially literacy and extension services, and

in other infrastructures such as facilities for irrigation, drainage, and other forms of water control, must play an important role in these developments. Many of these require major public investments, but the ability and willingness of farm people to take advantage of the increased availability of educational and extension services or the public provision of certain types of infrastructure can come about only through changes in the nature of private investment, especially in human capital but also in on-farm physical capital.

(*c*) Demographic change which accompanies the process of agricultural transformation and economic development is a crucial element in agricultural supply response. To an important extent these changes are initiated by improvements in public health which result in sharply decreased mortality, particularly infant and child mortality, and in control and/or eradication of debilitating diseases which make human labor less productive than it would otherwise be. However, many of the demographic changes which occur have their roots in the individual decisions of farm people to make greater investments in human capital in the form of greater education and better nutrition for their children and to have fewer children, as other forms of saving and provision for old age become available, as labor markets improve, and as there is an increased awareness of opportunities outside of the agricultural sector. Such demographic changes alter the nature of agricultural production, lead to increased use of nontraditional inputs, and to a greater reliance on markets, and thus alter the nature of supply response to prices and other factors.

(*d*) Naturally, the role of government in this process is important, and there are many areas in which, and points at which, government intervention is both necessary and desirable. But this should not be allowed to obscure the fact that governments are continually tempted to intervene when they should not and in ways which may seriously impede agricultural development and distort the incentives and signals which prices provide in modern agriculture. Marketing boards which supposedly regularize the flow of product from producer to market or stabilize extreme price fluctuations frequently hold down the prices producers receive; protection of domestic industry, such as fertilizer, serves to make more costly the things that farm people buy; taken together, serious consequences may follow, as the infamous case of rice production in Thailand serves to indicate.

While all of these arguments suggest that increased production is more dependent upon factors other than price, they do not mean, as Johnson has so cogently pointed out (pp. 210–13), that prices do not matter very much and that they can be used to accomplish other goals and objectives. As he says:

> Prices do matter. Prices affect decisions made by farmers—how much fertilizer to use, how to allocate this land and labor among crops and whether it pays to invest in tube wells or in improvements or irrigation systems. But prices also matter to others who have direct relationship to agriculture—research institutions, producers of farm inputs, credit agencies, and extension agents. Where the price of fertilizer is five to ten times the price of grain, there is little point in research institutions undertaking research on methods of applying fertilizer or on crop varieties that will give a significant response to fertilizer. Firms will be reluctant to produce farm inputs for which demand is restricted by low farm-product prices. Similarly, the supply of credit—as well as the demand for it—is affected by farm output prices.
>
> If there is continuing investment in research resulting in a flow of new varieties, new methods of protecting plants from diseases, insects and rodents, investments and improvements in irrigation, and readily available supplies of modern inputs at reasonable prices, increase in [product] prices will evoke much larger increases in output than if some or all of these conditions are not met. . . . But this in no way implies that prices are not important. (pp. 211–12)

Because of the inevitable tendency of governments to interfere with markets and prices, however, the problems of untangling supply responses are made doubly difficult. In the short run price uncertainties may be reduced by such interventions, but reduced uncertainty is not at all clear in the long run. Uncertainties with respect to the behavior of government may be far greater than uncertainties with respect to the behavior of weather and markets. Supply response occurs in a complex and interrelated system of which government is one element. Prices and other factors such as those discussed above affect not only farm people but also numerous institutions related to agriculture and agricultural development. The dynamics of supply in developing nations and in agriculture in the process of transformation cannot be fully understood without taking these complex interrelationships into account. It is doubtful whether studies based on historical relationships of the output of a single crop, or the area devoted to its cultivation, in rela-

tion to past prices can shed much light on these issues or even on the role and importance of prices and markets.

Prospect

Since the publication of my own work on the subject—eons ago it now seems to me—there have been numerous well-done studies of supply response to price in both developed and developing countries. Real interest, however, centers on the dynamics of supply in agricultural sectors undergoing the transformation from traditional to modern agriculture. In this paper, I have emphasized the simplistic and relatively ad hoc nature of the basic model I used so long ago to study the response of U.S. farmers to price in the production of corn, cotton, and wheat in the period prior to the introduction of price supports and acreage allotments. It is inadequate, despite the many ingenious modifications and additions others have made to it, either to model dynamic optimization in response to changing prices or to understand the true nature of dynamic supply response in the context of a developing economy.

To overcome the first sort of inadequacy is a challenging intellectual problem from both a theoretical and an econometric point of view. I have, perhaps, dwelt overly long on some of the ways in which distributed lag models of supply response based on dynamic optimization under uncertainty can be developed for livestock and perennial crops. In defense, I plead current involvement in research on these problems, rather than a sense of their importance relative to the second group of difficulties I have discussed here. Given a sufficiently adequate data base and enough intellectual effort and ingenuity, I am confident that the former can be satisfactorily resolved.

The inadequacy of the basic supply response model to disentangle the forces shaping agricultural supply in the context of a developing economy is far more serious. We are lacking both the necessary theoretical and econometric tools and the basic data. To be sure there exist time series data and other information in scattered instances for individual crops in particular areas which make it possible to do the more standard types of analysis with or without modifications along the lines suggested in my discussion of livestock and perennials. Along these lines perennials, so important to the economies of many developing countries, appear to offer the greatest opportunities for fruitful research. But, at best, such studies can yield only a partial and limited understanding of the dynamics of supply in developing countries. These dynamics are the result of a complex interaction of household and economy, which extends beyond the demographic-economic interactions I discussed in an earlier paper (1974). A variety of institutions, markets, and other phenomena must be related to one another in a process which extends over both time and space. Neither the data nor the theory are at hand in any very complete form.

What hope have we then for understanding the dynamics of agricultural supply in developing nations and what are the prospects for fruitful research? Notwithstanding my pessimism about the current state of affairs, I am optimistic with respect to the future. Economists have become increasingly involved in the collection and analysis of basic data at the microlevel of household or firm by special surveys or using census instruments. More often than not surveys are the only way to collect information on household time allocation, adoption of modern agricultural practices, fertility, and labor force participation, and, for firms, on expectations, plans, and realizations. The last decade has witnessed a resurgence of interest in the "new home economics" and the development of new theoretical and analytical tools which can be applied equally to farm households in developing nations. New econometric techniques for the analysis of microdata, particularly categorical data from surveys, are being adapted from earlier uses in biostatistics and sociometrics (e.g., Nerlove and Press; Koenig, Nerlove, Oudiz). We can, by special surveys and these methods of analysis, gain considerable insight into many of the basic phenomena underlying supply response in transitional and developing agriculture, particularly with respect to the adoption of new techniques and the demographic-economic interactions at the microlevel which are so crucial. The tangled web of the effects of government interventions, investments in infrastructure and the development of markets may be less susceptible to purely econometric analysis, but considerable progress can be made in understanding these phenomena by in-depth case studies and clear, if simple, economic reasoning. Sophisticated econometric techniques and high-powered

economic theory are complementary, not antithetical, to case studies and common sense.

References

Arak, Marcelle. "Estimation of Asymmetric Long-Run Supply Functions: The Case of Coffee." *Can. J. Agr. Econ.* 17(1969):15–22.

———. "The Price Responsiveness of São Paulo Coffee Growers." *Food Res. Inst. Stud.* 8(1968).

———. "The Study of Brazilian Coffee." Ph.D. thesis, Massachusetts Institute of Technology, 1967.

Askari, H., and J. T. Cummings. *Agricultural Supply Response: A Survey of the Econometric Evidence.* New York: Praeger Publishers, 1976.

———. "Estimating Agricultural Supply Response with the Nerlove Model: A Survey." *Int. Econ. Rev.* 18(1977):257–92.

Bacha, E. L. "An Econometric Model for the World Coffee Market: The Impact of Brazilian Price Policy." Ph.D. thesis, Yale University, 1968.

Bateman, Merrill. "Aggregate and Regional Supply Functions for Ghanaian Cocoa, 1946–62." *J. Farm Econ.* 47(1965a):384–401.

———. "Cocoa in the Ghanaian Economy." Ph.D. thesis, Massachusetts Institute of Technology, 1965b.

———. *Cocoa in the Ghanaian Economy: An Econometric Model.* Amsterdam: North-Holland Publishing Co., 1968.

Behrman, Jere. "Econometric Model Simulations of the World Rubber Market 1950–1980." *Essays in Industrial Econometrics,* vol. 3, ed. L. R. Klein. Philadelphia, Penna.: Econ. Res. Unit, Wharton School of Finance and Commerce, 1969.

———. "Monopolistic Cocoa Pricing." *Amer. J. Agr. Econ.* 50(1968a):702–19.

———. "Price Elasticity of the Marketed Surplus of a Subsistence Crop." *J. Farm Econ.* 48(1966):875–93.

———. *Supply Response in Underdeveloped Agriculture: A Case Study of Four Major Annual Crops in Thailand 1937–1963.* Amsterdam: North-Holland Publishing Co., 1968a.

Carvalho, J. L. "Production, Investment and Expectations: A Study of the United States Cattle Industry." Ph.D. thesis, University of Chicago, 1972.

Chan Kwong Wah, Francis. "A Preliminary Study of the Supply Response of Malayan Rubber Estates between 1948 and 1959." *Malayan Econ. Rev.* 7(1967).

Dean, G. W., and E. O. Heady. "Changes in Supply Response and Elasticity for Hogs." *J. Farm Econ.* 40(1958):845–60.

French, B. C., and J. L. Matthews. "A Supply Response Model for Perennial Crops." *Amer. J. Agr. Econ.* 53(1971):478–90.

Gardner, T. W. "The Farm Price and Supply of Milk." *J. Agr. Econ.* 15(1962).

Gardner, T. W., and R. Walker. "Interactions of Quantity, Price and Policy: Milk and Dairy Products." *J. Agr. Econ.* 23(1972).

Griliches, Zvi. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica* 25(1957):501–22.

Halvorson, H. "The Response of Milk Production to Price." *J. Farm Econ.* 40(1958):1101–20.

Hartley, M. J. Correspondence related to the construction of econometric models for the supply of perennials, 1979.

Huffman, W. E. "Contributions of Education and Extension to Differential Rates of Change." Ph.D. thesis, University of Chicago, 1972.

———. "Decision Making: The Role of Education." *Amer. J. Agr. Econ.* 56(1974):85–97.

———. "Allocative Efficiency: The Role of Human Capital." *Quart. J. Econ.* 91(1977):59–80.

Jarvis, L. "Cattle as Capital Goods and Ranchers as Portfolio Managers: An Application to the Argentine Cattle Sector." *J. Polit. Econ.* 82(May-June 1974):489–520.

———. "Supply Response in the Cattle Industry: The Argentine Case, 1937–38 to 1966–78." Ph.D. thesis, Massachusetts Institute of Technology, 1969.

Johnson, D. G. "International Prices and Trade in Reducing the Distortions of Incentives." *Distortion of Agricultural Incentives.* Bloomington: Indiana University Press, 1978.

Jones, G. T. "The Influence of Price on Livestock Population over the Last Decade." *J. Agr. Econ.* 16(1965).

Koenig, H., M. Nerlove, and G. Oudiz. "Micro-Analysis of Realizations, Plans and Expectations in the IFO and INSEE Business Tests by Multivariate Log-Linear Probability Models." Paper presented at the Athens Meeting of the Econometric Society, 1979.

Krishna, R. "Farm Supply Response in India-Pakistan: A Case Study of the Punjab Region." *Econ. J.* 73(1963):477–87.

———. "The Marketable Surplus Function for a Subsistence Crop: An Analysis with Indian Data." *Econ. Weekly* 17(February 1965).

Malinvaud, E. "First Order Certainty Equivalence." *Econometrica* 37(1969):706–18.

Mascolo, J. L. "Expectations and Beef Cattle Industry in Brazil." Ph.D. thesis, Fundação Getúlio Vargas, Escola Postgraduada de Economia, Rio de Janeiro, Brazil, 1979.

Muth, J. F. "Optimal Properties of Exponentially Weighted Forecasts." *J. Amer. Statist. Assoc.* 55(1960): 299–305.

———. "Rational Expectations and the Theory of Price Movements." *Econometrica* 29(1961):315–35.

Nerlove, M. "Estimates of Supply of Selected Agricultural Commodities." *J. Farm Econ.* 38(1956):496–509.

———. *The Dynamics of Supply: Estimation of Farmers' Response to Price.* Baltimore, Md.: Johns Hopkins University Press, 1958.

———. "Distributed Lags and Unobserved Components in Economic Time Series."*Ten Economic Essays in the Tradition of Irving Fisher,* ed. W. Fellner et al., pp. 126–69. New York: John Wiley & Sons, 1967.

———. "Lags in Economic Behavior." *Econometrica* 40(1972):221–51.

———. "Household and Economy: Toward a New

Theory of Population and Economic Growth." *J. Polit. Econ.* 82(1974 No. 2, Part 2):S200–18.

Nerlove, M., and S. J. Press. "Multivariate Log-Linear Probability Models for the Analysis of Qualitative Data." Disc. Pap. No. 1, Center for Statistics and Probability, Northwestern University, 1976.

Nerlove, M., D. M. Grether, and J. L. Carvalho. *Analysis of Economic Time Series: A Synthesis*. New York: Academic Press, 1979.

Nowshirvani, Vahid. "Agricultural Supply in India: Some Theoretical and Empirical Studies." Ph.D. thesis, Massachusetts Institute of Technology, 1968.

———. "Land Allocation under Uncertainty in Subsistence Agriculture." *Oxford Econ. Pap.* 23(November 1971).

Schultz, T. W. *Transforming Traditional Agriculture*. New Haven, Conn.: Yale University Press, 1964.

———. "The Value of the Ability to Deal with Disequilibrium." *J. Econ. Lit.* 13(1975):827–46.

———, ed. *Distortions of Agricultural Incentives*. Bloomington, Ind., and London: Indiana University Press, 1978.

Stern, R. "The Determinants of Cocoa Supply in West Africa." *African Primary Products and International Trade*, eds. I. G. Stewart and H. W. Ord. Edinburgh, Scotland: Edinburgh University Press, 1965a.

———. "Malayan Rubber Production, Inventory Holdings and the Elasticity of Export Supply." *S. Econ. J.* 31(1965b):314–23.

Theil, H. "A Note on Certainty Equivalence in Dynamic Planning." *Econometrica* 25(1957):346–49.

Wallis, K. F. "Multiple Time Series Analysis and the Final Form of Econometric Models." *Econometrica* 45(1977):1481–97.

Wickens, M. R., and J. N. Greenfield. "The Econometrics of Agricultural Supply: An Application to the World Coffee Market." *Rev. Econ. and Statist.* 55(1973):433–40.

Zellner, A., and F. Palm. "Time Series Analysis and Simultaneous Equation Econometric Models." *J. Econometrics* 2(1974):17–54.

Note: The circumstances under which this lecture was written were such that some professional journals were unavailable for the author to check specific page numbers on all citations.

Inflation, Agriculture, and the Food Economy
(G. Edward Schuh, University of Minnesota, Chairperson)

Commodity Programs and Inflation

J. B. Penn

Inflation has been identified by many as the nation's number one economic problem. And that makes the theme of this plenary session—inflation and its pervasiveness in agriculture and the food system—especially timely. Unfortunately (and perhaps inexcusably), we have woefully little rigorous analysis of the subject to allow comprehensive assessment of impacts. We can, then, hardly be prescriptive. The role of the agricultural commodity programs in the performance of the national economy and their contribution to the persistent inflation is complex. The complexity has grown in this decade with the increased interdependence of the agricultural sector and the national economy.

This paper identifies and explores the major considerations necessary for full and complete analysis of the costs and benefits of these programs to society, especially the inflationary impacts. I will discuss the impacts of inflation on the agricultural sector and the commodity programs, the role of commodity programs in affecting the national price level, the mechanism by which agricultural prices are transmitted through the economic system, and some issues and research areas important to future public policy decisions.

Background and Current Setting

Agriculture has a dual role in inflation—it is both perpetrator and victim. And, of course, the distributive impacts are ever present; seldom are the groups that benefit from (cause) inflation the ones most immediately victimized by it. But everyone is eventually victimized by inflation. So, why this paradox? Why do people urge their special interest, such as the commodity programs, when short-term gains must surely be overtaken and hugely outweighed by long-run adversities?

Expectations and Self-Interest

We have seen another curious paradox in recent public opinion polls of the national mood. Most individuals feel they are doing well and have bright prospects. Yet, they feel that the country is in poor shape and has an uncertain future.

This split personality of the American public exhibits an incongruity between personal and national expectations which cannot exist forever. Individuals eventually will cease to prosper if the nation ceases to prosper.

This apparent irrationality may well derive from the subject of this session, inflation. It is directly related to the subject of this paper: the farm commodity programs, part of a growing concern over special interests versus the national interest.

A popular phrase, the "Me-First" decade (or generation) is used to characterize our present situation: one where people focus so closely on their own economic position that the national interests become blurred. This condition is not only condoned but supported by public policy. Such selfishness is most evident in efforts to control inflation. The public tells the opinion pollers that inflation is the nation's number one economic problem. Further, all agree that the most strenuous effort should be made to halt inflation, so long as the burden falls on someone else. The cry of the me-firsters is loudest when any attempt is made to rationalize federal programs—with a view toward improving efficiency and eliminating duplication—or to reduce the deficit of the federal budget. Such attempts inevitably run into one or another of the special interest groups.

When inflation becomes the perceived norm, the incongruity between personal and national expectations may not be so incongruous after all. Most people have found ways to beat the system. Some buy land or homes or other things that appreciate more rapidly than the cost of living. Government and private

---

J. B. Penn is Deputy Administrator for Economics; Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture.

sector workers have succeeded in getting their wages, salaries, and pensions indexed to the cost of living.

Does individual progress really go hand in hand with national deterioration? A positive response may unfortunately be the logical one. As individuals, we are earning more money and increasing our material levels of well-being, while at the same time, the country is losing ground. The national economy becomes less and less competitive with those of other nations (evidence the growing sentiment for protectionism). It becomes increasingly vulnerable to the actions of other nations, as the recent OPEC oil price increases have demonstrated.

Personal hopes, in the long run, must come into accord with national expectations. But, not the least of the evils of inflation is that it keeps postponing the day of reckoning. It keeps advancing the time when Americans must finally come to grips with the problem.

Old Paradigm of Commodity Programs

The commodity programs were inaugurated to alleviate low farm incomes experienced in the twenties. The income problem emerged as per capita incomes in the nonfarm economy rose to levels such that the demand for food became inelastic. Consumers could purchase all the food they needed. But, the farm sector productive capacity was far in excess of that needed to meet domestic and foreign requirements. The excess production brought sharply lower commodity prices and the resulting farm incomes were much lower than incomes in the nonfarm sector.

The initial programs were considered temporary, but the resource disequilibrium in agriculture was severe. Resource adjustment was much too slow for the problem to be quickly eliminated. Low incomes persisted and the programs have been continued, even to this day. Only in atypical periods, such as wartime and the recent 1973–75 period, have the programs been shelved.

These programs have incorporated a variety of methods to secure farm incomes at politically acceptable levels. For over three decades, the preoccupation was with supporting commodity prices. Maintaining prices above market clearing (equilibrium) levels proved to have many undesirable side effects. Uneconomic production was encouraged and consumption was discouraged. Surpluses, of course, accumulated. These results necessitated production control, and various means, usually involving some form of limiting the land input, were used. By the end of the sixties, price support loans, direct purchases, marketing quotas and orders, set-asides, diversion, acreage allotments, direct payments, and some other methods had all been used at various times to increase commodity prices and farm incomes. It all amounted to high costs for increasing farm incomes.

New Paradigm of Commodity Programs

The incomes problem in agriculture had seemingly become eternal as we entered the seventies. Huge commodity surpluses were in government stockpiles, vast acreages of cropland were idle, and the income transfers to the farm sector were large and growing. But, largely unnoticed, the needed sectoral resource (especially labor) adjustment had been slowly occurring over the years (Schuh). The resource disequilibrium was becoming less pronounced even though the symptoms lingered. And, just when the problem appeared to be most severe—the largest proportion of the cropland acreage capacity ever, almost one-fifth, was idle in 1972—a convergence of events produced a dramatic economic upheaval. Evidently, the sector was nearing relative resource equilibrium when the upheaval occurred.

The economic environment for agriculture is a much different one today than before the upheaval. Perhaps the most significant difference is the greatly increased importance of international markets. These now absorb one-third of the value of domestic production and the physical output from one acre of every three. While the incomes problem is no longer paramount in the new setting, equally serious problems have emerged. The instability of commodity prices and farm incomes is perhaps the major problem confronting the sector today. The potential instability is greatly increased by the international markets. They have added the foreign counterpart to the domestic sources of uncertainty and instability such as weather aberrations and economic and political vacillations.

The instability problem is made much more severe by the structural changes that have occurred in the farm sector over the years. Farmers, once able to endure periods of depressed economic conditions because of their

relatively low fixed costs and little use of industrial inputs, are unable to do so today. The cost structure of most farm businesses is significantly different today. Annual debt service and fixed-cost commitments must be met. Additionally, almost 60% of the annual production inputs are purchased, most from the nonfarm sector. The prices of many of these inputs have risen rapidly in this decade, even though unit costs (reflecting productivity) may have been rising less rapidly. This is an important source of cost-push inflation and is in stark contrast with former times when few inputs were purchased from the nonfarm sector and at much more stable prices.

Even though the structure of the farm sector was changing markedly, the basic structure of the commodity programs remained largely unchanged at the beginning of this decade. However, some modifications had been effected over the years to incorporate greater economic rationality. Further modifications have been made in the seventies, at least for the major crop commodities: commodity-by-commodity production restraints were discarded in 1970 in favor of constraining the total plant capacity; full separation of the price support and income support (direct payments) approaches, begun in the mid-sixties, was achieved in 1973; and, in 1977, the antiquated acreage allotment system was abandoned, downward flexibility for the price supports was adopted, additional commodities (rice and peanuts) were brought into the general program framework, and provisions for a price-stabilizing grain reserve were adopted. Direct purchase programs, market orders, import restrictions, and other programs, however, continue to be operated for some major and several minor commodities.

Perhaps the most significant change has been the separation of the price support and income support functions of these programs. This resulted from recognition of the distortions arising from holding commodity prices above market clearing levels, not the least of which was the reduced competitiveness of U.S. commodities in export markets. This separation was completed in the 1973 Farm Bill when the target price-deficiency payment scheme was adopted. This program allowed the price supports to be set at relatively low levels, generally below the market prices, thus largely avoiding the distortions. Deficiency payments now provide the income support formerly provided through price supports. Direct payments, of course, can also contribute to inflationary pressures in the economy, even though prices are not immediately affected.

Transmission of Inflation

An important aspect of the role of commodity programs in inflation is the way in which commodity prices are passed through the economic system. The prices of many agricultural commodities seldom enter directly into determination of the composite national price level. Rather, as raw materials, they influence, to varying degrees and after lags of varying lengths, the prices of final (consumer) products which do enter directly into determination of the national price level. Agricultural commodities may be sold directly to consumers (e.g., fruits and vegetables) and, in this case, their prices are consumer prices; used as raw materials for manufacture of finished food products (e.g., wheat for bread), hence are reflected indirectly through the food component of the consumer price index (CPI);[1] used as raw materials for industrial products (e.g., soybean oil for paints and varnishes) and are also subsequently reflected indirectly in the appropriate category of the CPI; and sold for export, priced in the international commodity markets, thus are not reflected directly in the national price level, but influence the level of domestic prices.

The relative proportion of products sold directly to consumers and their importance in total food expenditures is small—valued at $3.5 billion or 1.5% of total food expenditures.

The prices of commodities that serve as raw material for food products are indirectly reflected in the food component of the CPI. The food component at present has a weight of 18% of the CPI, indicating that this proportion of total consumer expenditures is for food at home (12%) and away from home (6%).

As the primary linkage of commodity prices to the national price level, hence inflation, is through retail food prices, it is instructive to look at the relative importance of commodity prices in food prices. Some notion of this may be gained by examining food expenditures (price times quantity). The farm value of commodities in 1978 comprised 26% of total expenditures and 32% of expenditures for

[1] The all-food component of the CPI also reflects prices for food products that do not have a domestic farm origin. These include imported foods, fish and nonalcoholic beverages.

domestically produced farm foods (excludes imported foods, fish, and nonalcoholic beverages). Thus, the value of farm commodities in total domestic food expenditures comprises only about one-third, meaning that the remaining two-thirds are accounted for by nonfood inputs.

The food manufacturing and distribution sector—performing the functions of transforming domestic raw farm products into finished foods—contributes about twice as much to food costs as do commodities. Thus, labor, energy, packaging, advertising, and profits have about twice as much impact (through food prices) as raw commodity prices on the national price level. Of these, labor (wage rates) is by far the largest, accounting for about one-half of the marketing bill. Food containers and packaging materials are the second largest, followed by rail and truck transportation.

An increasingly important factor in food price inflation is the large service component (an added product attribute). This is a response to changing consumer preferences arising from demographic and age distribution shifts, the changing role of women, income growth, and other factors characteristic of our population.

Illustrating the relative impacts of commodity price changes, a 10% increase in all commodity prices, *ceteris paribus,* would increase short-run food prices about 3.3%. Likewise, a 10% increase in retail food prices would add about 1.8% to the inflation rate. The extent and rapidity of raw material price impacts on retail prices depend, of course, on the mix of commodity price increases (reflecting their relative importance) and on the ability of firms at each stage in the food system to pass through the price increases to the next stage, a function of their market power.

With this background, I now turn to examining the commodity programs, first as a victim, then as a perpetrator of inflation.

Inflation Impacts on Commodity Programs

There is a circularity in inflation and agriculture, both in terms of price transmission and in the formation of expectations that perpetuate inflation. Price increases are soon incorporated into decisionmakers' expectations; they become the perceived norm. These inflation expectations are in part self-fulfilling; they create demands for greater economic protection. As each group attempts to beat the system, to protect their self-interest, they seek enhancement of the commodity programs to protect them against inflation. The interest groups press their demands upon the Executive Branch and the Congress. Often they are successful: decisions are frequently taken in a micro-context and another incremental contribution is made to perpetuating the expected inflation.

Inflation affects the farm sector in the short run through the costs of inputs. As noted above, 60% of the annual production inputs are purchased from the nonfarm sector. The prices of these inputs are largely determined by forces in the nonfarm economy. Cost increases are quickly reflected in these input prices and the imperfect structure of the inputs industries means these are quickly passed on to farmers.

The major long-run effect of inflation is perhaps in the way it affects the prices of fixed assets, primarily land for agricultural purposes. The effect is especially pronounced for farmers who have purchased land in this decade, when the average annual price increase has been 12 %. The result is, of course, increased cost of production, further creating incentives to seek enhancement of the commodity programs to reduce the risk associated with the large investment.

The inflation-induced production cost increases also affect the cost of operating the commodity programs. An obvious example is the milk price support program which indexes the level of support to the formula-determined parity price. The milk price support was $4.28 per hundredweight in 1969; today, it is $10.76, an increase of 151% for an average annual increase of 15%.

There are adverse impacts of inflation on agriculture other than the commodity programs. These are treated in the other papers and are outside the scope of this discussion.

Commodity Program Impacts on Inflation

There is little doubt that the commodity programs, to the extent they are successful in achieving their purpose, contribute to inflation. And, they do so in a number of ways other than a direct increase in prices.

The programs serve to reduce the economic risk associated with the production of a specific commodity. They limit the downside risk on price, enabling farmers to increase

their financial leverage and encouraging lenders to lend more. This increased leverage and capital availability allows farmers to bid up the price of assets, especially land. Related, the programs also serve to influence farmers' long-term expectation about the profitability of production. More positive expectations are factors encouraging expanded asset acquisition, again usually resulting in increased asset prices.

To the extent that the programs lead (rather than lag) production cost increases, they serve to widen the cost-price spread, at least temporarily. This, in turn, stimulates greater use of inputs and expanded asset acquisition. However, the long-run average cost eventually will increase and any advantage from the wider spread is eliminated. The increased demand for inputs will result in increased input prices, especially for those products in the most heavily concentrated markets. The cumulative cost increases (land and other inputs) from these effects become reflected in the long-run average cost and subsequently in higher product prices. But, the higher long-run average cost creates new demands for enhancement of the commodity programs and the cycle starts again.

The commodity programs also may produce other secondary impacts as they influence the CPI. The federal budget today approaches $505 billion, of which some $160 billion (32%) is for federal programs that are directly or indirectly indexed to the CPI (i.e., the benefits of outlays are tied to the "cost of living" as measured by the CPI). These include such programs as social security, supplemental security income, military and civilian government employee retirement programs, the food stamp program, and the like. Although not direct, a reasonable rule of thumb for measuring the second-round impact is that each 1% increase in the CPI increases federal budget outlays by $1.0 billion to $1.5 billion.

A commodity price-food price-CPI increase has even more far-reaching impacts. About 23 million (23.7%) of the total labor force of 97 million workers are unionized and most have contracts with cost of living adjustments tied to the CPI. Thus, wage increases follow price increases. And, this is not limited only to unionized workers. Nonunion workers frequently follow the lead of the unions, emulating their wage demands. Thus, there is some "demonstration effect" with varying time lags. Wage increases are, of course, eventually reflected in the prices of the final products and the general price level. Many of these products are agricultural production inputs. The higher prices result in higher production costs for farmers. This full-circle transmission of commodity price increases gives rise to the so-called "ratchet effect": the eventual increased costs are largely inflexible downward while commodity prices are not. This produces another well-known condition, the "cost-price squeeze."

The capitalization of the commodity program benefits into land and other fixed asset prices also may produce a short-run inflationary effect. However, the longer-term effect of this capitalization may be much more serious as it affects entry, exit, and the structure of the farm sector.

Although the payments programs are less inflationary than price supports, they can have an adverse inflationary effect. To the extent inflation is demand-pull, the transfer payments to the farm sector undoubtedly increase this pressure. And, to the extent the payments increase the budget deficit, there are inflation impacts through debt service and impacts that can extend even to the value of the dollar in international currency markets. These are the little explored areas in assessments of commodity program impacts.

In addition to the price support-loan and payments programs, other commodity programs such as federal market orders also contribute to inflation, if only in a small way (Dobson and Salathe, Jamison). While they do stabilize prices, they also do so at somewhat higher than competitive levels.

Food Prices and Inflation—A Historical Perspective

The supply and demand conditions underlying price formation for commodities are affected by many factors that serve to cause price volatility. These sources derive from domestic weather and natural phenomena (diseases, pests) and, much more important since the early seventies, from world weather and world economic and political events.

A review of the historical role of commodity prices/food prices in inflation indicates that in eighteen of the twenty-nine years since 1949 food prices contributed less than one percentage point to the overall rate of inflation (table 1). In twenty-two of those years, food prices

Table 1. Contribution of Food Prices to Inflation

Year	CPI Food	Change in CPI Food	Contribution to All-Item CPI[a]	All-Item CPI	Change in All-Item CPI	Increase in All-Item CPI Accounted for by Food[b]
			%			
1950	74.5			72.1		
1951	82.8	11.1	2.74	77.8	7.9	48.1
1952	84.3	1.8	.50	79.5	2.2	29.1
1953	83.0	−1.5	−.23	80.1	.8	0
1954	82.8	−.2	−.07	80.5	.5	0
1955	81.6	−1.4	−.26	80.2	−.4	0
1956	82.2	.7	.20	81.4	1.5	16.5
1957	84.9	3.3	.89	84.3	3.6	30.7
1958	88.5	4.2	1.19	86.6	2.7	51.6
1959	87.1	−1.6	−.46	87.3	.8	0
1960	88.0	1.0	.30	88.7	1.6	21.2
1961	89.1	1.3	.36	89.6	1.0	40.3
1962	89.9	.9	.26	90.6	1.1	26.4
1963	91.2	1.4	.29	91.7	1.2	26.0
1964	92.4	1.3	.26	92.9	1.3	22.0
1965	94.4	2.2	.44	94.5	1.7	27.5
1966	99.1	5.0	1.08	97.2	2.9	40.0
1967	100.0	.9	.21	100.0	2.9	7.4
1968	103.6	3.6	.83	104.2	4.2	19.7
1969	108.9	5.1	1.22	109.8	5.4	21.8
1970	114.9	5.5	1.38	116.3	5.9	21.2
1971	118.4	3.0	.81	121.3	4.3	16.1
1972	123.5	4.3	1.17	125.3	3.3	29.3
1973	141.4	14.5	4.11	133.1	6.2	52.8
1974	161.7	14.4	4.67	147.7	11.0	32.0
1975	175.4	8.5	3.15	161.2	9.1	23.3
1976	180.8	3.1	1.24	170.5	5.8	13.4
1977	192.2	6.3	2.62	181.5	6.5	29.1
1978	211.4	10.0	3.50	195.4	7.6	24.9

Source: Salathe and Boehm.
[a] The change in the CPI for food multiplied by its relative weight in the all-item CPI. The relative weight of food in the all-item CPI was 0.33 from 1950 through 1962, 0.22 from 1963 through 1965, 0.23 from 1966 through 1977 and 0.18 in 1978.
[b] Column 3 divided by annual change in the all-item CPI.

increased at a slower annual rate than the rate of inflation in the general economy. Food prices actually declined in four years, while the CPI has declined only once since 1949 (in 1955).

Food prices have increased 185% since 1950. Up to 1967, the increase was relatively slow; the average annual increase was 2.5%. Since then, however, the rate has accelerated, to an annual average rate of more than 7% (9% since 1972). The two largest year-to-year changes occurred in 1973 and 1974 when retail food prices increased 14% each year.

Future year-to-year increases in food prices will reflect more closely the underlying rate of inflation in the nonfarm economy, evidencing the importance of the nonfarm inputs and services in producing finished food products. However, significant aberrations will still come from short-run disruptions in the supply of and demand for raw farm commodities.

Issues and Research Areas

The overriding public policy issue is, of course, the elimination of the underlying causes of inflation in the national economy. Successful courses of action to achieve this have eluded policy makers since the late sixties, and no immediate solution is in sight. However, significantly slowing the rate of inflation will require a concerted effort across the entire economy, a lockstep approach to policy actions with few exceptions to special interest groups. There will be overriding social concerns that merit exceptions, but the means by which these concerns are treated will re-

quire close scrutiny to minimize economic distortions.

Research Areas

The major research need is the same one that Schuh noted in 1976: a greater understanding of how domestic agriculture and the national economy fit into a rapidly changing interdependent world. There is a great need for consideration of the farm sector-food system-macroeconomy relationships. The information from greater quantification and understanding of the relationships is a sorely needed input for public policy decision making. A primary area for research treatment is comprehensive analysis of macroeconomic impacts on the farm sector and food systems and, in turn, the impacts of these sectors on the macroeconomy. This is amply illustrated by the inflation issue.

The development of such research would enable more complete analysis of benefits, costs, and distributive impacts of the agricultural programs. More explicit considerations of the indirect and secondary consequences (alluded to above) could alter the estimated net benefits and policy conclusions about the programs. It could also suggest means by which the programs could be structurally improved.

There is a heightened awareness of the role of macroeconomic policies in determining the structure of the farm sector. Improved understanding of the sector-macroeconomy interdependencies and linkages could help identify and clarify often unrecognized policy impacts on farms by size, type, geographic location, form of business organization, and the like.

As inflation persists, questions about how particular groups will fare and about the role of particular programs under varying rates of inflation will become more frequent. Our present knowledge base for responding to these and related questions is inadequate.

References

Schuh, G. Edward. "The New Macroeconomics of Agriculture." *Amer. J. Agr. Econ.* 58(1976):802–11.

Dobson, W. D., and L. E. Salathe. "The Effects of Federal Milk Orders on the Economic Performance of U.S. Milk Markets." *Amer. J. Agr. Econ.* 61 (1979):213–27.

Jamison, J. A. "Marketing Orders and Public Policy for the Fruit and Vegetable Industries." *Trade and Develop.* 10(1971):223–92.

Salathe, Larry E., and William T. Boehm. "Food Prices in Perspective." USDA ESCS Agr. Info. Bull. 427, Jul. 1979.

Inflation and Productivity

Vernon W. Ruttan

Inflation and productivity are the most persistent economic problems confronting the U.S. economy. Both represent a serious threat to the position of the United States in the world economy and in world polity. Both are serious obstacles to achievement of a degree of equity in the quality of life which has come to be taken as a major goal of domestic economic policy. The central thesis of this paper is the dialectical interaction between inflation and productivity. Inflation dampens productivity growth and slower productivity growth contributes to inflation.

The National Economy

The rate of inflation has risen gradually from 2% per year or less in the 1950s and early 1960s, to the 4%–6% range in the late 1960s and early 1970s, and to the 6%–10% range in the mid- and late 1970s (fig. 1). The inability of the old macroeconomics to provide effective and acceptable guides to economic policy has induced the emergence of a new "rational expectations" approach to economic policy. The operating hypothesis of this school is that, in the presence of a public which is continually trying to outguess the government, monetary and fiscal policy interventions in response to cyclical changes in economic indicators can only assure continued high rates of both inflation and unemployment.

The leading exponents of the rational expectations school, barricaded behind the portals of the Federal Reserve Bank of Minneapolis, prescribe a policy of gradually slowing money growth and reducing the federal deficit. The approach must, they insist, be sufficiently gradual to avoid pathological withdrawal symptoms—but of sufficient magnitude and consistency to lead to expectations on the part of consumers, labor, and business that the policy will be continued (Federal Reserve Bank of Minneapolis 1978, 1979; Lucas and Sargent).

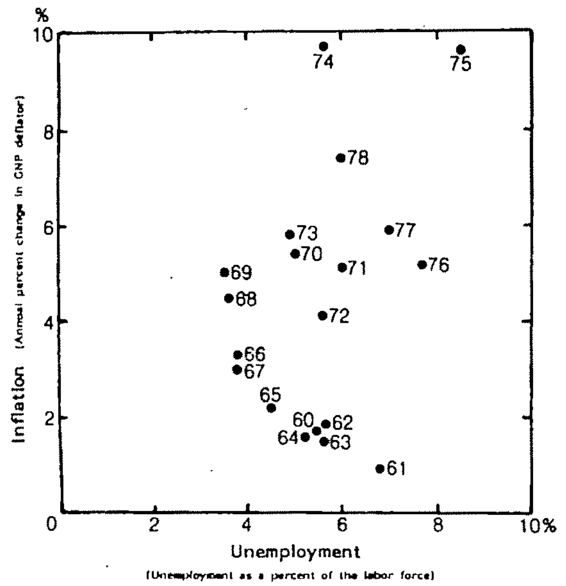
Concern about lagging productivity in the American economy is of somewhat more recent vintage than concern about inflation. Changes in the rate of inflation can be measured in terms of directly observed ratios that are more apparent to the individual consumer and producer than the implicit gross national product (GNP) deflator—the cost of a market basket at the grocery store relative to a weekly or monthly paycheck or by the prices paid for farm inputs relative to the prices received for farm production. Productivity is a somewhat more abstract—even arcane—concept. It is measured in terms of changes in a physical input-output ratio, such as change in output per unit of labor or in terms of changes in output per unit of total input. Its impact on the individual worker, on the firm, or on the total economy often is obscured by more transient sources of change. It must be interpreted to the citizen and to policy makers by a special breed of technicians—the growth accountants—who have not yet been able to agree on how productivity should be measured.

It is clear that the rate of productivity growth has declined in the private nonfarm sectors of the American economy (fig. 2). The Council of Economic Advisors noted in its 1979 report, "Between 1948 and 1965 (labor) productivity growth in the private non-farm sector averaged 2.6 percent per year. . . . Since 1973, private non-farm productivity growth has averaged less than 1.0 percent per year" (p. 67). A number of factors have been identified as accounting for a measurable share of the decline in productivity: (*a*) reduction in the rate of growth in capital investment per worker; (*b*) exhaustion of the backlog of technological knowledge that had emerged during the depression and World War II; (*c*) demographic changes in the labor force, particularly the increase in younger workers and women; (*d*) increased regulation to reduce the disposal of residuals into the environment and to pro-

---

Vernon W. Ruttan is a professor in the Department of Agricultural and Applied Economics and in the Department of Economics, University of Minnesota.

The author is indebted to Willard Cochrane, John Helmberger, Yoav Kislev, Philip Raup, G. Edward Schuh, James Simler, and Luther Tweeten for comments on an earlier draft of this paper.



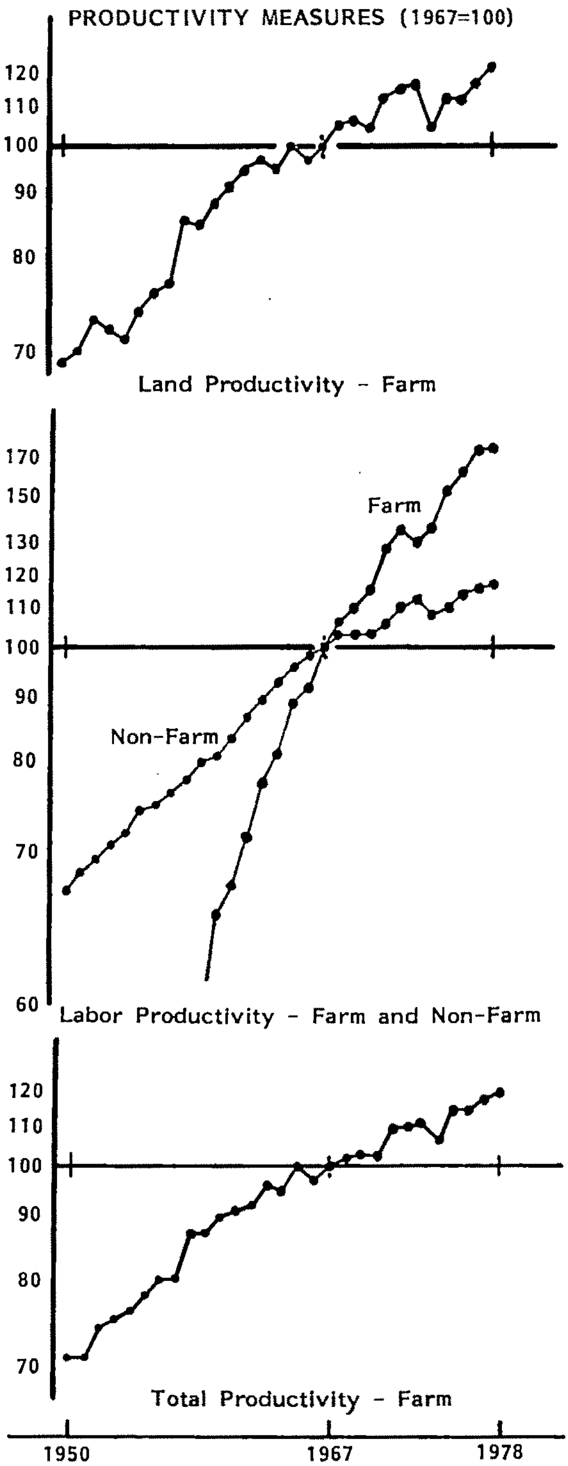
Source: Evenson, Waggoner and Ruttan. Productivity measures for the agricultural sectors from Durost and Black. Productivity data for the nonfarm business sector are from the Council of Economic Advisors.

Figure 1. Inflation and unemployment 1960–78

tect the health and safety of the labor force; and (*e*) increases in illegal activity (Denison 1978).

What is the impact of inflation on productivity? Friedman, in his Nobel lecture, argues that inflation leads to inefficiency, because it makes market prices a less efficient system for coordinating economic activity. Its impact is particularly corrosive on the functioning of capital markets. It contributes to a decline in the rate of savings and to the distortion of investment patterns. A consequence of inflation which appears to have been overlooked is the erosion of the capacity of public sector institutions to provide the services needed to enhance productivity in the private sector. Edward Denison (letter), our most careful analyst of the sources of productivity growth, after reviewing the literature on the effects of inflation on productivity, concludes "that inflation impairs productivity seems certain. But I have no idea how much it may have done so from 1973 to 1976."

What is the impact of the decline in productivity on inflation? Clearly, an economy in which labor productivity is increasing at 1.0% per year can provide its citizens with smaller annual increases in real income than an economy in which labor productivity is rising at between 2.0% and 3.0% per year. If labor,



Source: Federal Reserve Bank of Minneapolis, 1979.

Figure 2. Productivity measures 1950–78

management, and government come to accept productivity growth in the 1.0% range as "normal," there is no reason why low productivity should represent a source of inflation.

However, if workers expect real wage increments in the 3.0% range—on top of wage adjustments necessary to compensate for anticipated inflation—a decline in the rate of growth in productivity can represent a significant source of inflation. The importance of lagging productivity as a source of inflation, particularly in the short run when structural rigidities impose severe limitations on the flexibility of prices and wages, will depend on how expectations about both productivity and inflation enter into the complex economic and political bargaining among workers, management, and government.

The rational expectations school would presumably argue that in the presence of correct and consistent policy with respect to money supply, budget deficit, and exchange rates, any inflationary impact of a downward shift in the rate of productivity growth would be temporary. In a world characterized by substantial structural rigidity, I would expect that a continuation of the low productivity growth rates of the last several years will lead to intensified stress between workers, management, and consumers over the partitioning of the limited growth dividends that become available.

The Agricultural Sector

The same general forces that have operated to influence productivity growth and inflation in the national economy have also impinged on the agricultural sector.

Some intuitive insight regarding the short-run effects of inflation on the agricultural sector may be generated by examining the behavior of the series on prices received by farmers for commodities, prices paid by farmers for inputs, and the "parity" index. In general the index of prices received rises more rapidly than the index of prices paid during very rapid inflation. However, when the general price level is rising at a more moderate rate, prices paid tend to rise more rapidly than prices received.

The only rigorous empirical examination of the effects of inflation on prices received and paid by farmers with which I am familiar is the series of papers by Luther Tweeten and his associate of Oklahoma State University (Tweeten and Griffin). Tweeten's empirical estimates indicate that the effect of a 1% increase in the general price level is to raise the index of prices paid by farmers by 1% and to leave the prices received by farmers essentially unchanged. I personally have some difficulty accepting Tweeten's result that a 1% increase in the general price level has almost no effect on prices received. He arrives at this conclusion by an estimate that the increase in farm level demand that would otherwise be generated by inflation is approximately offset by increases in the cost of marketing services associated with inflation, leaving prices at the farm level essentially unchanged.

While the impact of inflation on current account is negative, the impact on capital account remains ambiguous. No one has, to my knowledge, successfully separated the impact (*a*) of land productivity increasing biological technology; (*b*) of labor productivity increasing mechanical technology; (*c*) of competition between agricultural and nonagricultural uses for land; and (*d*) of general inflation on changes in the price of land. The most successful efforts to untangle these interrelated forces have been made in a series of papers by Melichar (1978a, b). Conventional wisdom, based on comparisons of the increase in farm land prices with increases in farm operators' income, suggests a decline in the return earned from land ownership. Melichar points out, however, that during the 1950–70 period a combination of productivity growth, farm price programs, and changing land/labor and capital/labor ratios modified the historical relationship between land prices and farm operator income. During this period the rate of return to land ownership, even on current account, increased substantially. Since 1970, however, agriculture has experienced a land market boom in which anticipated capital gains have been used to finance current cash flow requirements. And the ratio of debt service costs to earnings on farm assets have exceeded the heights that preceded the land market crash of the early 1920s.

The high debt service to earnings ratio would not be particularly serious if real and nominal interest rates were still in the traditional 4%–6% range. With nominal interest rates averaging near 12%, a modest decline in the rate of cash flow can have very serious repercussions in the farm real estate market. The only thing that would be worse than continued inflation would be deflation! A major source of uncertainty for those who must do outlook work is whether the same set of political forces will be generated to validate inflated

land market prices again in the early 1980s as in the mid-1970s.

Productivity growth in the agricultural sector, measured in either partial (i.e., labor) or multifactor terms, continues at a more rapid rate than in the private nonfarm sector (fig. 2). I do not know why the difference continues. Given the adjustments that have occurred in the agricultural sector of the 1920–70 period, I would have expected greater convergence. I would also have expected the level of capital intensity that has emerged in the agricultural sector, significantly higher than in the industrial sector, to act as a factor dampening productivity growth.

Several hypotheses commend themselves to further investigation. Ben-Zion and I have shown that investment in research and development (R&D) in the private nonagricultural sector is quite responsive to economic fluctuations. The supply of technology to the agricultural sector may be less influenced by fluctuations in economic activity than in the industrial sector. Public sector research and development remains the primary source of agricultural technology, particularly the biological technology which has expanded the capacity of crops and animals to respond to higher levels of industrial inputs. The demand for technological change in agriculture continues to be driven by the product market and land market treadmill phenomenon.

The continued high rate of productivity growth in the agricultural sector cannot obscure, however, the fact that the rate of productivity growth in agriculture has slowed down over the last decade. While debate over measurement and the dating of turning points continues, I see no way to interpret the data plotted in figure 2 other than to conclude that the rate of productivity growth in agriculture has fallen below the level that prevailed over the first two decades after World War II. It may not be a coincidence that the timing of the decline coincides with the rapid expansion of agricultural exports in the late 1960s (Schuh).

Some Emerging Issues

In the closing sections of this paper I address three additional issues related to productivity in American agriculture. First, I raise the question of whether American agriculture is as productive today as we have become accustomed to believe. Second, I raise the question of whether we are continuing to make the investments required to release the technical constraints on agricultural productivity. Third, I raise some questions about the institutional constraints on productivity growth in American agriculture.

How Efficient Is American Agriculture?

In 1947, Schultz argued that the agriculture of the United States "did not come anywhere near meeting the standard of efficiency set by the American economy" (p. 646). A few years later, Byron Shaw, then Director of U.S. Department of Agriculture's (USDA) Agricultural Research Service, called attention to the narrowing gap between crop yield and livestock efficiency ratios realized by farmers and the results obtained from experiments and performance tests.

These concerns were largely forgotten in the 1950s and the 1960s. American agriculture was the wonder of the world—capable of meeting the food and fiber demands of the American economy, of filling the gap arising from rapid population growth in the developing countries, and of meeting the demand for feed-grain-based livestock production in Western Europe, Japan, and in the higher income socialist countries. By the mid-1970s, however, we were again being confronted with a new series of challenges regarding both the technical and institutional efficiency of the system of agricultural production that had emerged in the United States over the last half century.

Comparative historical evidence suggests that the capacity of the American agricultural system to meet domestic and foreign food and fiber requirements has been based at least as much on slow growth of demand for agricultural commodities by American consumers as on high rates of productivity growth. Output per hectare of a number of individual crops, maize in particular, is high relative to other countries. But average agricultural output per hectare of cropland remains low relative to the levels that prevail in many other developed and developing countries. The rate of growth of agricultural output since 1950 has averaged little more than 1.7% per year—well below the 2%–4% "modern" growth rates achieved by many developed and developing countries.

The serious issues confronting U.S. agricultural performance in the future are (*a*) whether the U.S. agricultural research system is main-

taining its capacity to support productivity growth, and (*b*) whether the institutional constraints which condition the structure of American agriculture are becoming an increasing burden on productivity growth.

How Strong is the Scientific and Technical Basis for Agricultural Productivity Growth?

This question, like the previous one, is not easily answered. Clearly, research at the state agricultural experiment stations and related institutions within the U.S. Department of Agriculture and in the private sector has failed during the 1970s to maintain the momentum for growth that characterized the 1950s or 1960s or that was expected at the time of the joint Department of Agriculture-State Experiment Station study of research needs in the 1970s (USDA). Research budgets have shown no real growth when measured against growth in the GNP deflator and have declined when measured against an index of costs of scientific manpower. Research expenditure, as a percentage of sales, has declined sharply for field crops, declined modestly for horticultural crops, and has risen significantly for livestock. And the mission of the agricultural research system has been broadened to include a range of environmental and consumer protection and enhancement roles that did not exist a decade and a half ago.

Agricultural research is clearly undervalued in the United States. Marginal rates of return in the range of 25%–50% per year have been estimated for a large number of commodities and for the research system as a whole (Evenson, Waggoner, Ruttan). Rates of return in this range induce a warm glow of self-satisfaction in the hearts of agricultural research administrators. When taken seriously they indicate substantial underinvestment in agricultural research.

Several hypotheses can be suggested for the failure to push research investment closer to an equilibrium. At the state level, the spillover of the impact of research on productivity into other states, estimated to be in the 50% range, seems clearly to be a factor limiting state expenditures on agricultural research. At the federal level, it seems apparent that the slippage in research support has been at least in part a result of the expediency of budget making in an inflationary environment rather than a conscious decision to cut back on either public or private investment in agricultural research. At the federal level, the substitution of a bureaucratic objective function for a social welfare function also appears to play a significant role. While productivity growth leading to a relative decline in the price of farm output can result in both higher net income to farmers and lower food costs to consumers, it also, under the price programs that have prevailed since the 1930s, imposes budget costs on the U.S. Treasury. The effect is to translate a social benefit into cost when viewed narrowly from the Office of Budget and Management or the Office of the Secretary of Agriculture. A rate of productivity growth just sufficient to keep commodity prices from rising is preferable from a bureaucratic perspective to the higher rate of productivity growth that would optimize the social rate of return to agricultural research.

Institutional Constraints on Productivity Growth

In addition to these built-in biases toward underinvestment in agricultural research, there have been a number of institutional changes in the economy which appear to have a negative impact both on the productivity of our agricultural research effort, as measured by the rates of return to agricultural research, and on the productivity of the agricultural sector, as measured by the rate of productivity growth.

We have, during the years since World War II, erected an incentive structure in American agriculture that has induced inefficient substitution of material inputs (capital and operating expenses) for land and labor. The constraints imposed on land use during most of the 1950s and 1960s led to excessive substitution of chemical inputs for land. The tendency was reinforced by institutional factors that failed to communicate the externalities resulting from increased levels of chemical inputs in terms of costs to farm producers. By the mid-1960s, the set of inefficient incentives for chemical-land substitution was supplemented by a tax policy that has had the effect of inducing inefficient substitution of capital for labor. We also have built a set of institutional constraints that impinge on the productive use of agricultural resources. One of the more obvious cases is the impact of market regulation on the shift of milk production from low- to high-cost locations. Efforts to manage more efficiently the spillover costs of chemical technology are in some cases having a sub-

stantial negative impact on R&D productivity, particularly in the pesticide, herbicide, and animal drug fields.

Perspective

In closing, I would like to come back to the issue of the interaction between productivity and inflation. During the half-century between 1920 and 1970, the focusing device that directed productivity growth in American agriculture was the declining real price of energy. The declining prices of energy induced the substitutions of mechanical power for animal power and labor, and substitution of yield-increasing and yield-protection chemical technology for land (Hayami and Ruttan; Binswanger and Ruttan).

Since the early 1970s, the price of energy has risen relative to most other inputs. I do not know whether energy prices will continue to rise relative to other inputs during the coming decades. However, it is very difficult for me to believe that they will decline as during the 1920–70 period. This means that the focusing device for scientific and technical effort that we have relied on for more than half a century is obsolete. A new focusing device will have to be found.

This leads me to anticipate a period of relatively slow growth in total productivity. In many respects the next several decades could parallel the lag in productivity in U.S. agriculture between 1895 and 1925. At that time, the closing of the land frontier induced a new land-saving biological and chemical technology. During the next decade I expect that we will be devoting increasing effort to the search for new energy-saving technologies.

What does this mean for the American economy? It means that it is unlikely that the economy can depend, as it has in the recent past, on productivity growth in the agricultural sector to dampen the impact of inflation on food prices (Schuh). If in addition to slow productivity growth, export demand remains strong, the effect of competition between foreign and domestic consumers on food prices will become more intense. The U.S. economy is past the era when transfer of resources from the agricultural to the nonagricultural sector, through either the labor market or the product market, can significantly enhance national productivity growth. And the nation may find great difficulty, if efficient new sources of productivity growth in agriculture are not found, in avoiding substantial resource transfers from the nonagricultural to the agricultural sector. The signals that such a transfer is under way will be masked for a considerable period by the slow growth of domestic demand for farm products, the large share of production that now moves into export, and the heavy absorption of grain production by the domestic livestock sector.

References

Ben-Zion, Uri, and Vernon W. Ruttan. "Aggregate Demand and the Rate of Technical Change." *Induced Innovation: Technology, Institutions and Development*, ed. Hans P. Binswanger and Vernon W. Ruttan, pp. 261–75. Baltimore, Md.: Johns Hopkins University Press, 1978.

Binswanger, Hans P., and Vernon W. Ruttan. *Induced Innovation: Technology, Institutions and Development*. Baltimore, Md.: Johns Hopkins University Press, 1978.

Council of Economic Advisors. *Economic Report of the President together with the Annual Report of the Council of Economic Advisors*. Washington, D.C., 1979.

Denison, Edward F. "Effects of Selected Changes in the Institutional and Human Environment upon Output per Unit of Input." *Survey Current Bus.* 58(1978):21–44.

Denison, Edward F. "Letter." 13 Apr. 1979.

Durost, Donald D., and Evelyn T. Black. *Changes in Farm Production and Efficiency*. USDA ESCS Statist. Bull. 612, Nov. 1978.

Evenson, Robert E., Paul Waggoner, and Vernon W. Ruttan. "The Economic Benefit from Research: An Example from Agriculture." *Science* 205(1979): 1101–7.

Federal Reserve Bank of Minneapolis. "Rational Expectations—Fresh Ideas that Challenge Some Established Views of Policy Making." *1977 Ann. Rep.* Minneapolis, Minn., 1978.

Federal Reserve Bank of Minneapolis. "Eliminating Policy Surprises: An Inexpensive Way to Beat Inflation." *1978 Annual Report*. Minneapolis, Minn., 1979.

Friedman, Milton. "Nobel Lecture: Inflation and Unemployment." *J. Polit. Econ.* 85(1977):466–67.

Hayami, Yujiro, and Vernon W. Ruttan. *Agricultural Development: An International Perspective*. Baltimore, Md.: Johns Hopkins University Press, 1971.

Lucas, Robert E., Jr., and Thomas J. Sargent. "After Keynesian Macroeconomics." *Fed. Reserve Bank of Minneapolis Quart. Rev.*, pp. 1–16. Spring 1979.

Melichar, Emanuel. "The Relationship between Farm Income and Asset Values." *Food and Agricultural Policy Issues*, ed. Luther Pickrel, pp. 194–200. University of Minnesota Agr. Extens. Serv. Rep. 71, 1978a.

Melichar, Emanuel. "Relationships among Farm Capital, Income and Debt." *Food and Agricultural Policy Issues*, ed. Luther Pickrel, pp. 252–56. University of Minnesota Agr. Extens. Serv. Rep. 71, 1978b.

Schuh, G. Edward. "The New Macroeconomics of Agriculture." *Amer. J. Agr. Econ.* 58(1976):802–11.

Schultz, Theodore W. "How Efficient Is American Agriculture?" *J. Farm Econ.* 29(1947):644–58.

Shaw, Byron T. "The Role of Research in Meeting Future Agricultural Requirements." *Agronomy J.* 45(1953):307–15.

Tweeten, Luther, and Steve Griffin. *General Inflation and the Farming Economy*. Oklahoma State University Agr. Exp. Sta. Res. Bull. P-732, Mar. 1976.

U.S. Department of Agriculture, and Association of State Universities and Land Grant Colleges. *A National Program of Research for Agriculture*. Washington, D.C., 1966.

The Distributional Consequences of Recent Inflation

K. L. Robinson

Income redistribution is an inevitable by-product of inflation, simply because all prices do not move upward at the same rate. The most recent period of accelerated inflation in the United States, that is the period beginning in 1972 and continuing up to the present time, has been characterized by extremely diverse changes in income within agriculture because the prices for different commodities have peaked at different times and have risen by widely varying amounts. Income redistribution also has occurred because factor price ratios have changed. Appreciation in land values has redistributed income from new entrants to those retiring from agriculture. Debtors clearly have gained relative to creditors. But I do not propose to dwell on these more obvious effects of inflation. Instead, I intend to focus on those aspects of recent inflation that appear to be somewhat unique or different from what we have experienced in the past. I shall begin with an analysis of interregional income transfers resulting from the widely divergent changes in commodity prices that have occurred since 1971. I shall turn next to the effect of recent inflation on income inequality within agriculture, that is on what may be referred to as the "Pareto" distribution of income. Third, I will examine the possible long-term consequences of recent changes in relative factor prices; and finally, I will comment briefly on the distribution effects of changes in food prices.

Regional Effects

Few generalizations can be made about the distributional consequences of recent inflation because of the diversity of price movements. Gains and losses among farmers have been associated with their product mix, when they sold or priced their output, their dependence on purchased feed, and when they began farming. Some regions clearly have gained much more than others and this in turn has influenced relative rates of inflation in land values.

It is difficult to sort out the effects of general inflation from other factors which have contributed to the erratic behavior of farm prices since 1971. There is no simple way in which this diversity in price behavior can be expressed, but one can highlight the differences by noting the range over which major commodity prices have moved since 1970–71 and in what year prices peaked. The peak season average price for wheat (which occurred in 1974) was more than three times the average price prevailing in 1970–71 (table 1); at the other extreme, the peak increase in the price of eggs over the same period was only 66%. These figures do not take into account the changes in prices that have occurred since 1978.

The diversity in price behavior, especially between grains and livestock products, is striking. Grain prices peaked earlier and at much higher levels relative to 1970–71 than livestock prices. This had the effect of redistributing income within agriculture. Grain producers gained relative to grain feeders in the mid-1970s. The aggregate net income of farmers in North Dakota, to take the most extreme case, more than quadrupled between the early and mid-1970s. But in states that rely on purchased feed, such as New York, the aggregate net income of farmers actually declined during this period.

Maximum changes in aggregate net farm income for each state were calculated for the period 1971–78 in order to obtain some indication of relative gains which farmers in different areas have experienced during the recent period of accelerated inflation. Maximum gains calculated as a percentage of aggregate net farm income in 1970–78 ranged from less than 50% in most of the northeastern states (with the exception of Maine) to over 200% in North

---

K. L. Robinson is a professor of agricultural economics, Cornell University.

Table 1. Peak Prices in the Period 1972 to 1978 and the Ratio of Peak Prices to Season or Annual Average Prices in 1970–71

Commodity	Ratio of Peak Price to 1970–71 Average[a]	Peak Year
Wheat	3.06	1974
Corn	2.52	1974
Cotton	2.51	1976
Hogs	2.32	1978
Soybeans	2.26	1978
Milk	1.83	1978
Beef	1.73	1978
Eggs	1.66	1976

Source: Computed from USDA *Agricultural Prices*, annual summary 1975, 1978.
[a] Based on season average or annual average prices, not individual months.

Table 2. Maximum Changes in Net Farm Income and Increases in Land Values between 1971 and 1978 for Selected Groups of States

Region	Increase in Land Prices, 1971–78	Maximum Increase in Net Farm Income[a]	Ratio: Land Price/ Income
	(%)	(%)	
Corn Belt	241	166	1.45
Great Plains	160	164	.98
Southeast	112	110	1.02
Northeast[b]	133	38	3.50

Source: Calculated from USDA *State Farm Income Statistics*, Supplement to Statist. Bull. No. 609, Sep. 1978, and *Agricultural Statistics*.
[a] Based on the percent increase in the aggregate net farm income of each state, adjusted for inventory changes, from 1970–71 to the peak year between 1972 and 1977.
[b] Excluding Maine.

and South Dakota, Washington, Oregon, Arizona, and Illinois.

Wide differences also exist among states in the rate at which land prices have appreciated. As one would expect, states in which incomes have gone up the most also tend to have experienced larger increases in land prices. Based on a superficial examination of the state data, it appeared that a first difference analysis relating maximum changes in net farm income to changes in land values would produce interesting results. But the R^2 value turned out to be relatively low, thus indicating that only a small part of interstate differences in the behavior of land prices since 1971 can be attributed to relative rates of change in farm incomes. In a few regions, there was consistency among states in the relationship between changes in income and land prices, but not in others.

States which exhibited reasonably uniform behavior were grouped together and the percentage changes in both land values and net farm income were then calculated. Regions were omitted in which there was considerable variation among states in the behavior of land prices and incomes. In the West, for example, land values have gone up much less in California than they have in Oregon, Washington or Idaho. Substantial differences also can be observed within the Mountain states and among those that make up the "Old Cotton South."

Percentage increases in land values from 1971 to 1978 were approximately equal to the maximum increase in net farm income for the group of states chosen to represent the Great Plains (table 2). A similar relationship prevailed in the southeastern states, but in the Corn Belt land prices rose almost 50% more than the maximum increase in farm incomes. The divergence between the maximum increase in land values and net farm income was even greater in the Northeast. Land values more than doubled in that area between 1971 and 1978, but this occurred despite a very modest increase in net farm income. Nonfarm demand for land obviously has played an important role in accelerating inflation in land prices since 1971, and perhaps more so in the Northeast than in the Midwest or the Great Plains.

Income Inequality

One can be reasonably confident in concluding that recent inflation has contributed to a greater degree of income inequality among regions and types of farms, but it is less certain what effect it has had on the incomes of those operating large as compared to small-scale or medium-sized farms. Inflation has made our statistics relating to farm sizes (which are based mainly on gross sales categories) almost meaningless (Stanton). Inflation also has added to the difficulties one encounters in attempting to compare the distribution of income over time. We know that gains in income are correlated with gross farm sales, but we do not know precisely how much of the recent increase in net income on large farms is attributable to inflation and how much to other factors. Again, differences in product mix affect the distribution. Large farms producing wheat, corn and soybeans probably increased

their share of total income during the mid-1970s, but not all large farms produce grains. Many of them specialize in the production of commodities whose prices have risen much less than the overall rate of inflation. Over the period from 1971 to 1978, for example, the incomes of cattle ranchers, feed lot operators, poultrymen and many of those producing vegetables for processing lagged behind. At the same time, those at the lower end of the income distribution, regardless of their product mix, were receiving more income from off-farm sources. Thus, it is not clear that the "Pareto" distribution of income has, in fact, been altered significantly as a result of recent inflation although it is possible this has occurred.

The most recent period of inflation has been accompanied by exceptionally large seasonal changes in prices. Increased volatility in prices may be attributable in part to more speculative trading on the part of those who have become disenchanted with the stock market and are turning to commodity markets in an attempt to "beat inflation." One of the by-products of increased volatility in prices has been to afford opportunities for exceptional gains to those who have been either very astute or lucky in the time they chose to sell or price their crop. The timing of transactions has become a critical management decision. Optimum timing of wheat sales in 1978–79, for example, could have added as much as $2 per bushel to a farmer's return. Soybeans is another crop in which timing of sales has been especially important. The 1979 July futures price, for example, has ranged from around $6 to over $8.50 per bushel.

I have no information which would enable me to determine what types of farmers have been most successful in timing their sales, but my guess is that the larger farmers who are well-financed and have relatively modest debts have been more successful in exploiting seasonal price changes than have small farmers and new entrants. The former have access to more information and can afford to hold their crop in anticipation of a rise in prices later in the season or even in subsequent years. Thus, my hypothesis is that recent inflation has widened income differentials among farmers producing similar products (mainly grains) and that these differences are associated with management skills related to the timing of sales or transactions on the futures markets.

Relative Changes in Factor Prices

The distribution effects of changes in relative factor prices or costs are even more difficult to identify than those associated with changes in product prices. One of the obvious differences between the most recent period of inflation and those experienced earlier is the relative rise in the price of energy and petrochemicals, including nitrogen fertilizer. Farmers who use abnormally large amounts of energy, such as those who depend on deep wells for irrigation, obviously will be disadvantaged in the future relative to those who rely on natural rainfall or gravity irrigation. Those farming soils with low inherent productivity and no livestock also may find their relative advantage declining as a result of the rise in the cost of nutrients. But thus far, these changes in the cost of energy and petroleum-based products have had little impact on the regional distribution of income.

Since my interest is in attempting to identify what is unique about recent inflation, I chose to compare changes that occurred during this period with those that took place during earlier periods of inflation. Two earlier periods were selected for comparative purposes: the first was the period from 1940 to 1949 during which the rate of inflation was more nearly comparable to what we have experienced recently; the second was from 1960 to 1969 when inflation was proceeding at a much slower rate.

Three price series or index numbers were selected to represent changes in the prices of the major factors or inputs in agriculture (land, farm wage rates and an index of tractor and farm machinery prices). The percentage change in price that occurred in each of the three periods of inflation was then calculated. These percentage changes in factor prices were divided by the percentage change in industrial wholesale prices in order to form a ratio which shows the relative change in factor prices which took place during each period of inflation. The index of industrial wholesale prices was chosen as the denominator or deflator because it is broadly based and is a reasonable indicator of the underlying rate of inflation for the economy as a whole. The percentage increase in farm prices during each period was also divided by the percentage change in industrial wholesale prices to determine what changes may have occurred in the overall terms of trade of farm products.

Table 3. Relative Price Changes in Three Periods of Inflation

Period of Inflation	Percentage Change in Industrial Wholesale Prices	Ratio of Change in Each Index to Industrial Wholesale Prices: All Farm Products	Farm Land	Farm Wage Rates	Tractors and Farm Machinery
1940–49	+71	2.1	1.6	3.3	1.1
1960–69	+11	1.1	6.0	5.5	3.0
1971–78	+84	1.0	1.8	1.0	1.3

Source: Calculated from data in *Agricultural Statistics*, 1952, 1967, and 1978, and the *Economic Report of the President*, Jan. 1979.

The results of these calculations are shown in table 3.

The increase in average farm prices between 1971 and 1978 was about equal to the increase in industrial wholesale prices over the same period. In this respect, the recent period of inflation differs substantially from the 1940s. During the earlier period, farm prices rose much more than industrial prices.

Machinery prices have risen more than industrial prices since 1971, but this should not be considered unusual since it is consistent with what happened in the 1940s and 1960s. In fact machinery prices rose more relative to both industrial and farm prices in the 1960s than they have since 1971.

Average farm wage rates increased no more rapidly than industrial prices between 1971 and 1978. In the 1960s, the increase in farm wage rates was 5.5 times the percentage increase in industrial prices. If recent trends persist, there will be less incentive to substitute capital for labor over the next few years than there was in the 1960s.

As everyone is aware, land values have gone up relative to both farm and wholesale prices. But this is not a new phenomenon. Land prices actually rose more relative to farm product prices in the 1960s than they did between 1971 and 1978.

An increase in land prices relative to the prices of farm products has important long-run distributional consequences. It changes the distribution of returns among factors, increasing the proportion which flows to land and decreasing the proportion which goes to reward labor and management. It also distorts decision making, rewarding those who are successful in land speculation relative to those who are simply good farm managers. Returns from appreciation in land have exceeded returns from farming in recent years as Breimyer and others have pointed out.

Inflation in land values also may serve to widen income differentials among farms. Established farmers and those already more financially secure in the community can generally outbid new entrants for whatever land becomes available, thus tending to reinforce existing income inequalities.

If inflation persists, an increasing proportion of the land is likely to be owned by those who have no interest in actually farming the land. Since land is looked upon as a hedge against inflation, few will want to sell it. Wherever possible, it will be passed on within the family. But many of those who inherit land will elect to rent it rather than to farm it. This will lead to further separation of land ownership from farm operation.

Separating or divorcing land management from farm management, while inconsistent with the Jeffersonian ideal, need not be disastrous for agriculture provided those who own the land are content with a modest current return on their investment and take a long-term interest in preserving the land. Many farms are now being rented for less than a farmer would have to pay if he owned the land. Furthermore, by divorcing ownership from farm management, the real estate tax burden, which has become of increasing concern to farmers as land values have risen, would be shifted to those who want to speculate in land.

It is not too soon for agricultural economists to begin thinking more seriously about alternative institutional arrangements that would encourage good land management and make it possible for those with limited capital to enter farming. This is precisely what the British tried to do in the late 19th century with their tenure reform laws. The aim was to protect the rights of tenants, to reward them for any improvements they made on the land, and to encourage practices that would maintain the long-term productivity of the land. In the past we have tried to solve the problem of entry

into agriculture by liberalizing credit. This has had the effect of reinforcing inflation in land prices. We should now consider the possibility of creating new institutions that will enable those with limited capital to become farmers and let those who have the capital and want to speculate in land to pay the taxes and carry the costs of land ownership.

Distributional Effects of Inflation in Food Prices

In contrast to their behavior in the 1960s, food prices have risen more than other items in the Consumer Price Index (CPI) since 1971. Gains from higher food prices have been shared by farmers and middlemen. Because food expenditures absorb a higher percentage of the income of families at the lower end of the income scale than those at the upper end, this transfer of income through higher food prices is equivalent to a regressive sales tax. Furthermore, since much of the meat, fruits and vegetables purchased by low income families is produced on farms with sales in excess of $100,000 per year, one might argue that the transfer of income associated with recent inflation in food prices has been socially undesirable.

The poor obviously have been compelled to pay more for food, but the incomes of the "poorest of the poor," or at least those participating in the Food Stamp program and those receiving Social Security benefits, are now indexed to take account of inflation. Food stamp benefits are adjusted semi-annually in accordance with changes in the cost of a market basket which includes foods typically consumed by low income households. Social Security benefits, likewise, are now raised automatically each year and, in fact, have gone up more than the Consumer Price Index since 1971. Thus it is probably fair to conclude that those most adversely affected by rising food prices are families whose incomes are just above the poverty line or those who elect for a variety of reasons not to participate in the Food Stamp program. With increasing indexation, including mandated increases in minimum wages and higher medicaid payments, the social consequences of inflation in food prices are less serious now than they would have been five or ten years ago.

Conclusions

Few generalizations can legitimately be made about the distributional consequences of recent inflation. Income has been redistributed within and between agriculture and the rest of society, but in ways that can be described with only slight exaggeration as capricious. Commodity prices have behaved erratically in response to a multitude of exogenous forces, including poor crops in the Soviet Union, drought and a short growing season in the U.S. in 1974, the entry of China into the world market on a much larger scale, a freeze in Florida, too much or too little rain in California, and a poor soybean crop in Brazil. Differences in the timing and magnitude of changes in commodity prices have produced wide fluctuations in farm incomes and unequal benefits among producers. Gains in real income were concentrated chiefly among grain producers in the mid-1970s, but subsequently those selling cotton, citrus and other fruits also benefited. More recently, incomes have been redistributed from consumers to livestock producers, not because of inflation, but mainly because the liquidation phase of the cattle cycle has ended.

Existing inequalities in income within agriculture probably have been reinforced by rising land prices and the ability of farmers with secure financial resources to hold commodities and to take advantage of abnormally large intra- as well as inter-seasonal fluctuations in prices. But not all those operating large farms have gained since many produce commodities whose prices during much of the past seven years have gone up less than the overall rate of inflation. This includes producers of eggs, fed beef and a number of vegetables sold for processing. Small-scale and part-time farmers have benefited as much from increasing off-farm income as they have from higher farm prices.

Income also has been redistributed among factors of production and between generations. Most, if not all, of the benefits from rising commodity prices have been capitalized into the value of farm land. This is nothing new, but the effects have been far from uniform among states.

Farm wage rates have risen less than the price of machinery, energy and fertilizer since 1972 which is a marked change from what happened in the 1940s and again in the 1960s. This reversal of past trends has not had much

effect as yet in altering factor combinations, but it is likely to do so in the future.

Finally, indexation of transfer payments, mainly Food Stamp and Social Security benefits, has reduced the potential adverse social consequences of rising food prices. This also has made it more difficult to determine precisely who wins and who loses from inflation. Some of the old rules about who benefits from inflation still apply. Debtors and those who bought land some years ago clearly have gained relative to creditors and new entrants into farming. But with more widespread indexation, even of private pension plans, and increasing public subsidies for medical care, housing and possibly home heating for the poor and elderly, the victims of inflation are less obvious.

References

Breimyer, Harold F. *Farm Policy: 13 Essays*. Ames: Iowa State University Press, 1977.

Stanton, Bernard F. "Some Political Arithmetic of Large and Small." Paper presented at Northeastern Agricultural Economics Council meeting, Newark, Delaware, 20 June 1979.

Inflation, Agriculture, and the Food Economy: Discussion

Wallace Barr

Our economy, of all economies in the world, should have the capacity for flexibility and dynamism beyond most others to achieve the basic economic goals of full employment, price stability, and economic growth. But, increasingly it appears our economic system lacks the adaptability and capacity to generate change. One reason for inflation being at, or near, the forefront as an economic problem is that we may have set our sights for economic growth, economic equality, and full employment at unrealistic levels. Our promises have led to highly stimulative monetary and fiscal policies. Combined with excessive regulation, they have resulted in an acceleration in the rate of inflation.

Our words and motives are contradictory. Baughman, in a recent speech, said that, "all too often we—

"Talk economic growth but act to restrict production;

"Talk free markets but act to restrict competition;

"Talk price stability but pass laws that directly raise prices;

"Talk full employment but pass laws and impose regulations that directly increase unemployment;

"Aspire to be rich but act to denigrate savings and investments;

"Label inflation public enemy number one but fail to attack it from all quarters." (March, 1979)

Each of the authors has lamented the acceleration in the annual rate of inflation. They have provided a useful basis for looking at some of the impacts and the relationships of inflation to productivity and food costs (Ruttan), commodity programs (Penn), and farm income distribution (Robinson). Little was said about the courses of action to contain inflation.

In light of this situation, I focus my discussion on some policies which have some potential to effectively reduce the annual rate of inflation.

Wallace Barr is an agricultural economist with the cooperative extension service at Ohio State University.

Policy Directions

If we want to design a policy to reduce the rate of inflation we must deal with two basic and highly interrelated questions. The first question is "What rate of inflation is desired?" or "What rate of inflation is tolerable?" The second is "What policy tools, or mix of tools, might best achieve the desired goals?"

A few limitations are in order. It is quite apparent there is too little research on inflation. But there is frequently a shortage of research. Any public policy initiated to combat inflation interacts with factors influencing the welfare of the private sector. The public and private forces can be complementary. But inflation containment policies are sure to conflict with the objectives of some group. Thus, we get into the emotional portion of the policy process in how and what tradeoffs will be made.

High employment levels, economic growth, economic equality, and price stability are all appropriate economic goals. But goals should be set at achievable levels. Each needs to be considered in light of other important goals—not irrespective of the effects on other goals.

The policies suggested below to influence the rate of inflation are just that—suggested. There is neither time nor the inclination to look at all the options or to exhaustively analyze them. Absent are specific magnitudes.

Balance the Budget

The most popular prescription, although not universally acceptable, is to balance the budget. In the legislative process, this policy carries a lower priority than tax reductions and additional spending to meet needs deemed

important. Though a balanced budget may not be absolutely essential to contain inflation, it merits major consideration due to the realities of today's political-economic climate.

The budget could be balanced by increasing revenues while slowing the rise in spending, or by cutting expenditures while maintaining or slightly cutting revenues. A compromise would be to at least halt the increase in spending. Following a series of large deficits it is encouraging that budgets are being subjected to critical review in an effort to lower budget deficits.

The major inflation containment impacts would be (*a*) reduced government employment and purchases of goods and services making more available to the private sector slowing price increases, and (*b*) reduced government borrowing permitting private demand for financing at somewhat lower interest rates. The results of such policies should be to increase capital spending and improve productivity, moderate the rate of inflation, and improve competitiveness in world markets. The major obstacle to a balanced budget is that attainment will probably mean slower economic growth rates.

Slower Expansion of Money and Credit

Any list of inflation containment policies includes slowing the expansion of money and credit. The major reasons for placing a high priority on this course of action is that, in the long run, all that monetary policy can influence is the general price level. And it may be impossible to contain inflation if money and credit are allowed to expand rapidly.

What constitutes an appropriate monetary expansion policy is subject to much debate. But in the years since World War II, consumer prices have advanced about 290%, the stock of money (M_1) increased 320% and, production of all goods and services rose nearly 300%. Thus, monetary growth roughly comparable with growth in production can finance increases in the general level of prices.

In a historical perspective, Baughman (Jan. 1979) cites the five-year period of 1960–65 when annual inflation was 1.6% as measured by the gross national product deflator and production increased at an average annual rate of 4.7%. M_1 increased at an average annual rate of 3.1% and M_2 by 6.4%. Monetary growth, economic growth, and inflation rose and unemployment declined. However, unemployment at 5.5% was deemed unacceptable and stimulative monetary and fiscal policies were pursued.

During 1977 and 1978, the basic money supply or M_1 grew at an average of 8% and 9% for the broader measure M_2. In this period (1977–78), investment in new plant and equipment was inadequate to maintain growth in industrial capacity and/or improve productivity. In the past three months (April-June, 1979) Foldessy points out that M_1 has grown at an 11.1% annual rate and M_2 at 11.2%. These rates far exceed the federally announced long-term growth rate targets of 4.5% for M_1 and 8% for M_2.

From a historical perspective these recent monetary growth rates, if inflation is to be contained, are excessive. In the 1960–65 period moderate inflation and rapid economic growth occurred with a money growth rate of 3% and 6.5% for M_1 and M_2, respectively. If price stability and moderate economic growth are to be the goals, M_1 and M_2 at somewhat lower levels would be in order.

Change the Income Tax Structure

The structure of our income tax system may contribute to inflation (Brake). Many groups have the power to negotiate, arbitrate, or set their incomes. They recognize the need to obtain a 14% increase in wages to net 7% after the tax increase if they are in the 50% bracket. Or that a 7% increase in wages nets only 4% to 5% after taxes.

The loss of incentives from moving to a higher tax rate with a lowering of before tax purchasing power (due to inflation) results in people searching for tax shelters, or writeoffs, or taking more time off, and/or tax cheating. It may be a factor in our relatively low saving rate.

Brake (and others) suggest that indexing the tax structure has appeal because the system would then be neutral to inflation. Congress would increase or reduce taxes as various needs arose. The expected results of neutralizing the income tax structure should result in improvements in price stability and economic growth.

Reduce Bureaucrat Overhead

We worry about inflation but pass laws that increase prices. Examples include recent increases in minimum wages, farm income sup-

ports, and restrictions on some industrial imports.

A policy of reviewing and reconsidering laws and regulations directly influencing prices in light of our relatively high inflation rates should be encouraged. Some may need to be repealed; some may need to be revised to lessen the inflationary impact. The laws designed to restrict competition or to permit groups to raise or maintain prices are those that should be considered.

Laws and regulations should promote competition wherever feasible; not restrain it. Some regulations impose compliance costs that exceed the problems they intend to alleviate. The most noted current example is airline regulation. The deregulation of airline routes, fares, and services is restoring a large measure of competition to this industry. Airline deregulation is demonstrating that restoration of competition is more effective than government regulators. Deregulation of the trucking industry should provide similar benefits, thus helping to contain inflation.

Toward an Inflation Policy

The current state of affairs in this nation provides an improved opportunity to change directions if, in fact, we want to contain inflation. Instead of living with accelerating inflation rates we can decide between the options of (*a*) a gradual reductions approach or (*b*) a more rapid or "shock" approach.

The gradual or rational expectations approach mentioned by Ruttan prescribes a policy of gradually slowing money growth and reducing the federal deficits. The idea is to avoid withdrawal symptoms, but to be of sufficient magnitude and consistency to lead to expectations by consumers, labor, and business that the policy will be continued. The weakness of this approach is that the policies may be abandoned before accomplishing the goal of reducing the inflation rate.

Some people feel the longer it takes to control inflation the less probability the task will be accomplished. This gives rise to the "shock" approach of declaring inflation an emergency. This means calling for emergency measures to control inflation by a specific time, say 1982. The specific measures identified earlier can be adopted in a magnitude determined by Congress and encouraged by the administration to attain the desired monetary growth and employment levels deemed appropriate.

The compelling evidence is that we have an economy that is inflation prone. It inflates easily because we have built in both private and government stimuli to expansion, while our resources do not provide for as much expansion as they once did. Consumer and worker groups use their power to avoid being a victim and investors look for inflation havens.

Since inflation does not arise from a single cause a few grand actions cannot solve the problem. Monetary and fiscal policies are a part of the package of policies that will be required. So are laws and regulations that increase costs, reduce competition, and unduly enhance price. Encouraging freer trade, adjusting income tax laws to provide incentives to invest and to work, and developing a domestic policy to encourage industrial efficiency, including energy, will be helpful in reducing the annual rate of inflation.

Actions to decelerate inflation will be painful to most citizens. But it could be worse for our political-economic system to do nothing.

References

Baughman, Ernest T. "The Control of Inflation." *Voice*, pp. 1–3. Dallas, Texas: Federal Reserve Bank of Dallas, May 1979a.

———. *Policies to Control Inflation*. Proceedings of The Farm Management Program, Dep. Agr. Econ., Purdue University, Jan. 1979b.

Brake, John R. *Inflation and the Myth of Tax Cuts*. Michigan Farm Economics, Dep. Agr. Econ., May 1979.

Foldessy, Edward P. "Pressure Mounts for Further Tightening of Credit." *Wall Street Journal*, 10 Jul. 1979.

Inflation, Agriculture, and the Food Economy: Discussion

Dale M. Hoover

The topic for this session is so broad and the economic shocks of the past decade have been so numerous it is not surprising that the preceding papers have ranged over a wide territory. The participants have presented a number of intriguing hypotheses and some very interesting facts. I will present a brief overview of inflation taken from the three papers and from my own assessment. Then I will discuss specific issues from each of the papers and raise some questions about inflation not covered here or in the agricultural economics literature.

Almost everyone agrees that inflation can be said to have occurred if the consumer price index (CPI) increases persistently. However, there is great confusion about the cause of inflation. An Environmental Protection Agency rule may be called inflationary. So too Occupational Safety and Health Administration regulations, frosts, floods, freezes, and droughts, but calling the proximate causes of advances of the components of the CPI the sources of inflation is a mistake. We need to examine the increases in demand that stand behind the advances of specific prices. Taken in the long run, inflation is caused by an increase in the stock of money relative to the quantity of real cash balances that households and business wish to hold at a given level of prices.

In a period of monetary expansion, households and firms find their cash balances increased. They are moved into a state of disequilibrium. They will pass the shock along as they increase their purchases of goods and services. As the sellers of these goods and services transmit orders to replenish their inventories, the shock wave spreads. Producers will probably not identify the increase in demand as a monetary phenomenon unless they already hold an expectation of inflation. The adjustment process will move through the market until all prices have advanced more or less equally.

Now let us look at the microeconomics of inflation in the farm sector. Gardner's model of marketing margins can be used even though it was not designed for inflation analysis. When demand increases, the elasticity of supply for farm products will be less than the elasticity of supply of processing inputs in the short run. This leads to an increase in the price of farm products relative to the processed product and in the "farmer's share of the consumer's dollar." But after the demand changes have worked their way through the processing factor markets, there will be no reason to expect relative price changes. The farmer's share can be expected to fall back to its former level.

Farm input markets will feel the increase in demand and prices will advance. Following an additional lag, asset values will adjust in the direction of restoring the original price/earnings ratio but we need to go cautiously here. It has been widely observed that the real rate of interest—that is, the nominal rate less the rate of inflation—often falls in a period of a rising rate of inflation. This makes borrowing a good thing for those persons who correctly anticipate the rate of inflation. These forces together may impart capital gains from land ownership in the short run. These gains may provide the basis for another round of increases if land price increases confirm past expectations and become a source of new expectations about the future.

There are three more lags that need to be discussed, all in the public sector. Congress tends to write farm laws in absolute terms and only occasionally to build in an escalator clause with a lag. Market prices outrun support prices, but at any hint of market softness there will be pressures from farmers to increase support rates, if net farm incomes fall as input prices catch up. The second lag is in the budgets of not-for-profit organizations such as the land grant universities. Deans and

Dale M. Hoover is a professor and an assistant department head in the Department of Economics and Business at North Carolina State University.

chancellors are not as aggressive as labor union leaders in getting escalator clauses for their associates. This lag reduces the rate of discovery of new techniques and after a considerable period leads to a slowdown in the growth of productivity in the farm sector. The third, but shortest, public sector lag is between Social Security payments and food stamps on the one hand and inflation on the other. This lag is short because of indexing written into the laws. As a consequence, any real income decline that arises because of inflation, or as a result of an attempt to slow it, are concentrated on taxpayers and persons who face reduced employment during recessions.

Now to comments on the papers. While I agree with Penn that we need research on the impact of inflation on agriculture, I do not believe cost-push is a defensible theory of inflation. Appeals to sacrifice as a cure for inflation are not effective except in the shortest of runs and only then if they alter consumers' and producers' expectations. In the face of persistent and increasing inflation they are of no value. In fact, they may confuse the electorate about the locus of responsibility for inflation. If I can convince Penn that money is the primary cause of inflation I can simplify his life and remove some of his worries. The milk program is not inflationary as are neither price supports nor direct payments. Let the monetary authorities have the praise and blame for inflation and let the Economics, Statistics, and Cooperatives Service get on to other issues.

Robinson's review of commodity and input prices covers a period which included monetary inflation as well as the shocks of OPEC and the Russian shortfalls in wheat production. Unfortunately, he confounds the results of inflation with all of the other changes that occurred between 1971–78. Useful and interesting though his analysis is, it does not leave us with a clear impression of the separate impact of inflation as it is classically defined. His analysis of the income distributional impact of inflation is somewhat "cleaner" because national policy has not yet been extended to include "wheat stamps" to recompense poor people for the export boom.

His analyses of the changes in the prices of farm inputs, farm products, and wholesale goods utilize first differences and fairly short periods. As a result the reported changes are very dramatic, perhaps too much so. If the starting and ending indexes of land values are divided by the starting and ending indexes of wholesale prices, the figure for 1960–69 is 1.6. This indicates a 60% increase in the purchasing power of land over industrial goods. Robinson's ratio of first differences for this period is 6.0. Even at a lower amplitude, Robinson has called our attention to some real puzzles that deserve further analysis.

Even though everything depends on everything else in economics, I am not persuaded by Ruttan that there is an important causal force running from productivity to inflation. With inflation at or above 10% and productivity falling one or two percentage points, surely we can neglect productivity as an important determinant of inflation. Labor expectations about productivity may be important in setting the terms for bargaining, but do they loom large relative to secular and cyclical shifts in the real demand for products, technological change that affects the demand for workers, and the rate of inflation existing before the recent declines in productivity? If labor demands lead to an increase in the growth of the money stock, inflation may result. The money stock is still the first round cause of inflation even though there may be a political or public choice process that links labor expectations to price levels in a second round.

Ruttan has stressed an important impact of inflation on productivity through the budget process of public institutions but there is a question about the length of the lag. For example, I am not convinced there was no growth between 1895 and 1925. I believe productivity accountants should examine the changes in the biologic stock in the agricultural sector in that era; the level of nutrients available to crops from centuries of soil building activity, the stock of diseases, and the stock of insects are examples. If the flows from these sources were properly measured, would we still conclude that technology and research had not had any impact or would we conclude that they offset a decline in productivity that would otherwise have emerged? Similarly, was the recent decline in productivity growth due to an undermeasurement of the land stock in the era of diversion and an overmeasurement since 1972?

Ruttan also presents an interesting hypothesis about cheap energy having provided the focus for technological change. Stated in its most optimistic form the induced innovation hypothesis argues that there is considerable payoff to research wherever you are stimu-

lated to invest resources. If this is true, then could not the energy shock provide a stimulus for more technological change?

In thinking ahead to this session I reviewed a considerable amount of the literature and was depressed with how little I found that is useful to an understanding of inflation in the farming and food sector. None of the work on margins I came across formally treats inflation as a problem. Most of the papers that purport to analyze inflation's impact on agriculture use no macro-variables. They simply build in the historical drift in real product prices and then attribute the decline in real farm prices to inflation. An exception is the paper by Shei and Thompson. Why have not we worked on the micro-foundations of inflationary price changes in some way analogous to the labor-search foundations of unemployment or to the disequilibrium market analyses produced by other economists? Since inflation appears to be an important and persistent phenomenon this appears to be an area in which we should launch new studies.

References

Gardner, Bruce L. "The Farm-Retail Price Spread in a Competitive Food Industry," *Amer. J. Agr. Econ.* 57 (1975):399–409.

Shei, Shun-Yi, and Robert L. Thompson. "Inflation and U.S. Agriculture: A General Equilibrium Analysis of the Events of 1973." Paper presented at American Agricultural Economics Association meeting, Pullman, Washington, 29 July-1 August 1979.

Valuing Nonmarket Goods: Conceptual and Empirical Issues (Virgil Norton, University of Maryland, Chairperson)

Approaches to Measuring Public Goods Demands

A. Myrick Freeman, III

Although some public finance textbooks still teach that public goods demands cannot be measured, substantial progress has been made in developing and implementing techniques for measuring one form of public good—the benefits of improving environmental quality. This paper presents a brief review of the three major approaches to estimation of demands and benefits and a somewhat more detailed discussion of those techniques which are based on market interactions between public and private goods. The analysis is limited to those public goods which are arguments in individual utility functions. Public goods which are inputs in production processes for marketed goods—for example, air quality in agricultural production—affect cost, supply, and factor demand functions and through them affect one or more of the following: output prices, factor prices, and profits (quasi-rents). The benefits of increases in public goods supply can be measured in a conceptually straightforward manner from observable market data. See Freeman (1979a) for an elaboration.

Individual Demands for Public Goods

The first step is to outline a basic model of individual preference and demand which incorporates a public good such as environmental quality as an argument in the utility function. This will establish the basis for describing various approaches. The analysis is limited to only one individual so that the problem of consistent aggregation to market demand curves can be ignored. Assume a utility function of the following form:

$$(1) \qquad U = U(\mathbf{X},Q),$$

where $\mathbf{X}$ is a vector of private goods, $\mathbf{X} = (x_1, \ldots, x_i, \ldots, x_n)$, and Q is the level of environmental quality taken to be fixed to the individual. Maximizing utility subject to a budget constraint

$$\sum_i p_i x_i = M,$$

where M is money income, leads to a set of demand functions

$$(2) \qquad x_i = x_i(\mathbf{P},M,Q).$$

Note that in general it is possible that environmental quality could be an argument in private goods demand functions.

The dual to the utility maximization problem can be stated as follows: minimize expenditures $\left(\sum_i p_i x_i\right)$ subject to the constraint that utility as defined by (1) equal or exceed some stated level, say U^*. The solution to this problem gives the expenditure function

$$(3) \qquad E(\mathbf{P},Q,U^*) = M.$$

The derivative of the expenditure function with respect to any price gives the Hicks-compensated demand function for that good, i.e.,

$$(4) \qquad x^*_i = \partial E/\partial p_i = E_{p_i}(\mathbf{P},Q,U^*).$$

The compensating variation and equivalent variation measures of the welfare changes associated with changes in market price can be interpreted easily in terms of equation (3). Similarly, the derivative of (3) with respect to Q gives the Hicks-compensated inverse de-

---

A. Myrick Freeman, III, is a professor in the Department of Economics, Bowdoin College.

The author is grateful to V. Kerry Smith for a number of helpful discussions of various aspects of the paper.

mand function or marginal willingness to pay for environmental quality, $w^*(Q)$,

$$w^* = -\partial E/\partial Q = E_q(\mathbf{P},Q,U^*). \tag{5}$$

The benefit to the individual for a nonmarginal increase in Q is:

$$b = -\int_{Q_1}^{Q_2} E_q(\mathbf{P},Q,U^*)dQ. \tag{6}$$

The main question addressed in this paper is under what circumstances and by what techniques information on (5) or (6) can be obtained.

Empirical Approaches

One approach involves analyzing data from market transactions in goods and services related to various measures of environmental quality. Under certain circumstances, the demand for improvement in Q can be estimated from market data on the demand for goods and services which have substitute or complementary relationships with Q. Examples of these approaches include: the use of property value differentials; household expenditures on cleaning, maintenance, and repair of materials damaged by pollutants; and travel costs incurred to participate in outdoor recreation.

The second approach is simply to ask individuals, through surveys and direct questioning, what value they place on a specified change in Q or how much Q they would "purchase" at a given stated price. One well-known problem with this approach is the incentives individuals may have to give biased answers for strategic reasons. In addition to these strategic biases, there is some evidence that certain structural characteristics of surveys have the potential for biasing responses. For example, in order to make the questions seem realistic, some surveys have stated that the vehicle for repayment will be an increase in the sales tax, or a surcharge on electric utility bills. If the respondents have some attitudes concerning the chosen means of repayment, this could introduce vehicle bias into responses. Also, in many surveys the questioner announces a value and then adjusts it upward or downward in fixed increments depending on the response. The starting point can also introduce a bias.

It appears to be possible, however, to design survey questions so as to eliminate the incentives for biased response. The general approach is to design the survey instrument so as to minimize the occurrence of any linkage between a subject's response and either an actual repayment or an actual outcome. But devices to eliminate incentives for biased responses also have a second effect. They reduce the incentive to provide accurate responses. An accurate response is one which is consistent with the behavior that would be revealed if the good in question could actually be offered in a market. In the real world, an individual who takes an action inconsistent with his basic preferences, perhaps by mistake, incurs a cost or a loss of utility. In the purely hypothetical survey situation, there is no cost to being wrong, and therefore no incentive to undertake the mental effort to be accurate. The more hypothetical the situation posed to the individual; that is, the further removed the situation is from his normal everyday experience, the less likely is the answer to be accurate. This problem has not yet been addressed seriously.

Another problem with surveys has to do with perceptions and how to portray accurately the hypothetical situation to respondents. For example, if the purpose of the survey is to estimate the benefits of a specified water quality improvement, the questioner must find a way to describe the improved water quality accurately and in sufficient detail so that all respondents are reacting to similar perceptions of water quality improvement. Some of the best survey studies have combined photographs with descriptive textual material, e.g., Brookshire, Ives, and Schulze, and Randall, Ives, and Eastman. But there are limits to the ability of both words and pictures to convey effectively all of the aesthetic dimensions associated with Q.

In summary, at the theoretical level the problems of bias, accuracy, and perceptions must give one pause about the effectiveness of surveys in measuring willingness to pay. However at the practical level there is very little evidence concerning the seriousness or the magnitude of the errors introduced by these three problems. It would be useful to have comparative studies of benefit estimates derived by alternative techniques. Few of these have been done (Knetsch and Davis; Brookshire, d'Arge, Schulze). In the meantime, information derived from such surveys can be considered useful but not definitive.

A third approach is to place proposals which consist of alternative levels of Q and asso-

ciated tax increases to referendum vote. Under certain circumstances the outcome of the voting process will be consistent with, and therefore reveal information about, the underlying demand curve for improved Q. The outcome of a referendum in any one jurisdiction only reveals whether the proposed level of Q and the associated tax burden were preferable to the status quo for a majority of voters. However, if the outcomes of elections or referenda in a large number of jurisdictions are observed simultaneously, it can be assumed that they approximate the median preferences in each jurisdiction. Then each jurisdiction can be taken as a sample unit, and the data on the quantity of the good or service, price or tax share, and socioeconomic characteristics such as income, education, and occupation can be pooled and analyzed by multiple regression techniques to determine the relevant price and income elasticities of demand. Examples of this approach include Bergstrom and Goodman, and Borcherding and Deacon.

Where all costs are financed through taxes in the voting jurisdiction and all benefits accrue to residents, voting can yield unbiased information on demand and on the optimum provision of Q. But where some of the benefits accrue outside the region, voting behavior does not capture all of the relevant demand for Q. And where some of the costs are shifted out of the jurisdiction, voters are not responding to the true price; thus voting reveals information about only a limited (and not the most relevant) portion of the demand function.

Market Approaches

In this section a priori assumptions are used to impose certain restrictions on the form of individual utility and demand functions. Different types of restrictions have different implications for the measurability of public goods demands from market data. The first assumed restriction leads to a situation in which it is impossible to estimate the demand for Q from market data.

A Hopeless Case

Suppose that the utility function is strongly separable with Q as the single argument in one of the subsets. In other words,

$$U = V[u^a(\mathbf{X}_a) + u^b(\mathbf{X}_b) + u^c(Q)],$$

where $\mathbf{X}_a$ and $\mathbf{X}_b$ are subsets of marketable goods. Strong separability means that the marginal rates of substitution between any pair of goods in $\mathbf{X}$ are independent of Q. Changes in Q have no effect on marginal rates of substitution of any of the marketable goods. Q can be excluded as an argument in all of the market demand functions. Although changes in Q affect utility, they leave no record of this impact in the data on market transactions. Thus in principle it is not possible to estimate the demand for Q from observable market data on transactions in $\mathbf{X}$ when the utility function is strongly separable in Q.

Strong separability is a property of two of the most commonly used functional forms for utility functions—the Cobb-Douglas and the constant elasticity of substitution (CES). This can be seen by writing them in their log transformations. Separability may be a characteristic of an important class of benefits. For example, those amenities of the urban environment which are not directly associated with private goods consumption may be separable. The option value associated with the preservation of unique natural environments is also likely to be separable (Cicchetti and Freeman).

Weak Complementarity

For some forms of utility functions, the private goods demand functions do contain Q as arguments:

$$x_i = x_i(\mathbf{P}, Q, M). \tag{8}$$

Suppose that this system of demand equations has been estimated econometrically and that the system satisfies the Slutsky conditions for integrability. Is it then possible to integrate this system to solve for the underlying utility function and expenditure function? If the answer is yes, then it would be possible to compute public goods demand or willingness to pay functions from market data whenever private good demand functions had this form.

The answer is that in general it is not possible to solve completely for the utility and expenditure functions with the information given. Mathematically the result of the integration contains unknown terms which are themselves functions of Q and the constants of integration (Mäler, pp. 183–9). It is necessary to impose additional conditions on the problem in order to solve for the unknown terms and determine the constants of integration.

The additional conditions involve what Mäler has called "Weak Complementarity."

Weak complementarity is defined by Mäler to occur if when the quantity demanded of a private good x_i is zero, the marginal utility or marginal demand price of Q is zero. The weak complementarity assumption would seem to apply to a number of useful situations. For example, the marginal value of water quality in a particular lake could be assumed to be zero for those people who did not use the lake for recreation. The marginal value of air quality over a particular residential site would be zero for those who did not live at that site.

Since direct application of the weak complementarity method as described here would require the econometric estimation of complete systems of demand equations, it would appear to be of relatively limited practical significance. Fortunately the weak complementarity conditions also permit the estimation of the demand price for Q without solving for the underlying utility and expenditure functions. This latter method requires only information on the demand for x_i, the weakly complementary private good. When Q increases, the demand curve for x_i shifts out. Mäler (pp. 185–6) has shown that the benefit of the improved Q can be measured by the area between the old and new demand curves for x_i. In those cases where weak complementarity is not strictly true, i.e., when the willingness to pay for Q is positive even with zero x_i, then this area understates the true demand for Q.

If the analysis uses the Hicks-compensated demand curve for x_i, the area between the curves is an exact measure of the compensating variation measure of benefits. If an expression can be formulated for this area as a function of Q, the derivative of this function with respect to Q is the marginal demand price for Q. Typically what is known is an ordinary demand curve, not a Hicks-compensated demand curve. Willig has established conditions under which areas under ordinary demand curves can be taken to be close approximations of the precise compensating or equivalent variation measures. A straightforward extension of Willig's analysis shows that if the income elasticity of demand for x_i is constant over the range of variation, his conditions also apply to areas between ordinary demand curves. Thus for practical purposes, the technique described here can be applied to market data. (See Stevens for an example.) The primary empirical requirement for utilizing this technique is that we be able to obtain econometric estimates of the demand function for the private good as a function of Q as well as prices and income. This requires observations of the market for x_i under different quantities of Q. If Q has never changed, there is no possibility of identifying the partial relationship between Q and the demand for x_i.

Perfect Substitutes

Mäler (pp. 116–18) has shown that the partial derivative of the expenditure function with respect to Q is equal to the price of the private good times the marginal rate of substitution between it and Q. This would be a useful practical result if it were possible to derive simple expressions for the marginal rate of substitution.

Suppose the utility function is weakly separable and is of the following form:[1]

$$(9) \quad U = V\{u^a(\mathbf{X}_a), [cx_i^{-\rho} + (1 - c)Q^{-\rho}]^{-1/\rho}\},$$

(x_i is not in $\mathbf{X}_a$). Given the separability assumption, the marginal rate of substitution between x_i and Q is independent of the quantities in $\mathbf{X}_a$. Then the marginal willingness to pay is

$$w^* = -P_{x_i}\left(\frac{c}{1-c}\right)\left(\frac{Q}{x_i}\right)^{1/\sigma},$$

where σ is $\rho - 1$.

In general, to use this formulation, we need to know both the elasticity of substitution, σ, and "c." There is one special case where the expression reduces to a usable term. If x_i and Q are perfect substitutes in consumption, the elasticity of substitution between them is infinite, and the expression for the marginal demand price of Q reduces to $P_{x_i}r$, where r is the equivalence or substitution ratio between x_i and Q.[2] If perfect substitutability can be assumed, r (or c) should be computable from known or observable technical consumption data.

The perfect substitutability assumption lies behind the "defensive expenditures" technique for estimating benefits of pollution control. Defensive expenditures (or what Zeckhauser and Fisher call averting behaviors) are expenditures made to prevent or counteract the adverse effects of pollution. If de-

[1] The following discussion is based on Mäler, pp. 178–83.

[2] $r = c/(1 - c)$. For example, if $c = .75$, then $r = 3$. This means that one unit of Y is a perfect substitute for three units of x_i.

fensive expenditures are a perfect substitute for reductions in the level of pollution effects experienced, then an individual can effectively purchase the optimal amount of Q through defensive outlays. In practice, defensive outlays which would be perfect substitutes for Q would be rare. There is no such thing as a perfect defense. There are some disutilities associated with pollution that cannot be prevented by further spending. This is equivalent to saying that σ is less than infinite. Hence, changes in defensive outlays are likely to give underestimates of the true benefits of the changes in Q. Nevertheless, recognizing this limitation, analysis of changes in defensive outlays related to pollution could substantially narrow our range of ignorance about benefits.

Hedonic Prices

The techniques described so far have been developed for the case where the level of public good provision or environmental quality is fixed and the same for all individuals. Although this represents one polar extreme, it is not descriptive of all possible cases involving public goods or environmental quality. Individuals can choose the level of consumption of local public goods through their choice of a jurisdiction to reside in. Also there are important cases where individuals have some freedom to choose their effective consumption of environmental quality through their selection of a private goods consumption bundle. Where these choices are possible, information on public good demand is embedded in the prices and consumption levels for private goods. For example, if air quality varies across space in an urban area, individuals may choose their exposure to air pollution through their residential location decisions. Residential housing prices may include premiums and discounts for locations in clean or dirty areas. It may be possible to estimate the demand for clean air from the price differentials revealed in private markets. The demand function for Q is estimated through a two-step procedure in which first the implicit price of Q is estimated by the application of the hedonic price technique, and then the implicit prices are regressed against observed quantities to estimate the demand function itself.

The hedonic technique is a method for estimating the implicit prices of the characteristics which differentiate closely related products in a product class (Freeman 1979b). Let **X** represent a product or commodity class. Any unit of **X** can be completely described by a vector of its characteristics. Continuing with the housing example, let c_i represent the specific characteristics of a structure and its lot, and Y_j represent neighborhood characteristics such as quality of schools, and Q represent air quality. Then for any unit of **X**, say x_i,

$$(10) \quad P_{x_1} = P_x(c_{11}, \ldots, c_{1i}, \ldots, c_{1n}, Y_{11}, \ldots, Y_{1j}, \ldots, Y_{1m}, Q_1).$$

The function P_x is the hedonic or implicit price function for **X**. If P_x can be estimated from observations of the prices and characteristics of different models, the price of any model can be calculated from knowledge of its characteristics.

The implicit price of a characteristic can be found by differentiating the implicit price function with respect to that characteristic. This gives the increase in expenditure on **X** that is required to obtain a model with one more unit of that characteristic, *ceteris paribus*. If (10) is linear in the characteristics, then the implicit prices are constants for individuals. But if (10) is nonlinear, then the implicit price of an additional unit of a characteristic depends on the quantity of the characteristic being purchased, and perhaps on the levels of other characteristics, too. Linearity will occur only if consumers can "arbitrage" activities by untying and repackaging bundles of attributes (Rosen, pp. 37–38).

Under some circumstances it may be possible to use the information contained in the implicit price function to identify the demand relationship for a characteristic—even if the characteristic is a public good such as environmental quality. First assume that each individual purchases only one unit of **X**, or if he purchases more than one, they are identical models. Otherwise the individual facing a nonlinear hedonic price function might be observed to act upon two different implicit prices for the same characteristic. Also assume that the utility function is separable in **X** and its characteristics. This makes the marginal rate of substitution between any pair of characteristics independent of the consumption of any good other than **X**. Without separability, the demand for a characteristic would in fact be a function of the consumption levels of other goods; and the estimation of the second stage demand function would require addi-

tional price and quantity data beyond that derived from the hedonic price function.

For the i^{th} individual, the quantity, Q_i, is known by observation and its implicit price P_{Qi} is known from the implicit price function. Can individuals' marginal willingness to pay functions be identified from these observations? The answer depends on the circumstances of the case. If the implicit price function is linear in Q, then it is not possible to identify a demand curve for Q. The price observation is the same for all individuals. However the marginal implicit price can be interpreted as the marginal willingness to pay or marginal benefit for small changes in Q for each individual. If equation (10) is nonlinear, the ability to identify the demand curve depends on the specification of the underlying model (Freeman [1979a] and Rosen).

If inverse demand functions for individuals can be identified, benefits of changes in Q can be calculated by taking areas under the demand curves bounded by the old and new levels of Q. Since these are not income-compensated demand curves, the areas are approximations of the true compensating variation measure.

References

Bergstrom, Theodore C., and Robert P. Goodman. "Private Demands for Public Goods." *Amer. Econ. Rev.* 63(1973):280–96.

Borcherding, Thomas E., and Robert T. Deacon. "The Demand for Services of Nonfederal Governments." *Amer. Econ. Rev.* 62(1972):891–901.

Brookshire, David S., Ralph C. d'Arge, and William D. Schulze. "Experiments in Valuing Non-Market Goods: A Case Study of Alternative Benefit Measures of Air Pollution Control in the South Coast Air Basin of Southern California." *Methods Development for Assessing Tradeoffs in Environmental Management*, vol. 2. Washington, D.C.: Environmental Protection Agency, 1979.

Brookshire, David S., Berry C. Ives, and William D. Schulze. "The Valuation of Aesthetic Preferences." *J. Environ. Econ. and Manage.* 3(1976):325–46.

Cicchetti, Charles J., and A. Myrick Freeman III. "Option Demand and Consumer's Surplus: Further Comment." *Quart. J. Econ.* 85(1971):528–39.

Freeman, A. Myrick III. *The Benefits of Environmental Improvement*. Baltimore, Md.: Johns Hopkins University Press, 1979a.

———. "Hedonic Prices, Property Values, and Measuring Environmental Benefits: A Survey of the Issues." *Scandinavian J. Econ.* 1979b.

Knetsch, Jack, and Robert K. Davis. "Comparisons of Methods for Recreation Evaluation." *Water Research*, ed. Allen V. Kneese and Stephen C. Smith. Baltimore, Md.: Johns Hopkins University Press for Resources for the Futures, 1966.

Mäler, Karl-Göran. *Environmental Economics: A Theoretical Inquiry*. Baltimore, Md.: Johns Hopkins University Press, 1974.

Randall, Alan, Berry Ives, and Clyde Eastman. "Bidding Games for Evaluation of Aesthetic Environmental Improvement." *J. Environ. Econ. and Manage.* 1(1974):132–49.

Rosen, Sherwin. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *J. Polit. Econ.* 82(1974):34–55.

Stevens, Joe D. "Recreation Benefits from Water Pollution Control." *Water Resour. Res.* 2(1966):167–82.

Willig, Robert D. "Consumers' Surplus without Apology." *Amer. Econ. Rev.* 66(1976):589–97.

Zeckhauser, Richard, and Anthony Fisher. "Averting Behavior and External Diseconomies." Mimeographed, 1976.

Values of Marine Recreational Fishing: Measurement and Impact of Measurement

Kenneth E. McConnell

There is a rich literature in economics dealing with the inefficiencies of the competitive allocation of open access resources. Economists working in the area of outdoor recreation have devised several methods for simulating market demand curves for estimating social benefits. Recreational fishing, most especially marine fishing, is one of those activities competing for the use of open access resources that requires the estimation of social benefit functions.

In the absence of good information about net social benefits for open access activities, decision makers tend to respond to measures which reflect the total level of economic activity. Decisions based on the level of economic activity can have rather severe consequences for nonmarket activities such as recreation. This bias is evident in the allocation of resources between marine recreational and commercial fishing. The history of fishery management in the United States, particularly on the East Coast, is almost exclusively that of commercial fishery management. The magnitude of commercial fishing is recorded in market transactions at harvesting, in processing and consumer levels, and by inputs such as vessel days at sea, fuel, and employment. However, for measures of the magnitude of recreational fishing, we have only the market value of inputs used in fishing such as boats, rods and reels, and other ancillary services. One result of relying on market data is to instill in policy makers the belief that fish are most valuably used in the commercial sector because only in that sector is the output sold on the market.

Economists can help improve resource allocation by applying their evaluation techniques to marine recreational fishing. In this paper, I report on two approaches to evaluation: the travel cost method (Dwyer, Kelly, Bowes) and the hedonic price method (Pollak and Wachter; Brown, Charbonneau, Hay; Bockstael and McConnell). The two approaches are similar in that they rely on observed behavior rather than responses to hypothetical questions. They differ in the extent to which they assume an individual can control his environment.

Economists view the efficient allocation of fish stocks between commercial and recreational fishing as the allocation which maximizes the present discounted value of recreational benefits plus commercial benefits, subject to a constraint on the biological growth of the fish stock. The solution to this problem yields a dynamic multiplier which can be interpreted as the user cost of catching fish. The optimal allocation between commercial and recreational use can be achieved by imposing a fee per unit of catch equal to the user cost. The user cost depends upon the discount rate, the response of catch to increased stock density, the response of commercial and recreational effort to increased catch, and the change in biomass growth caused by greater stock densities (for details, see McConnell and Sutinen). No economist would argue seriously that fisheries management requires simply the computation of user cost and the imposition of a fee per pound of fish landed equal to the user cost. Yet, the information required to calculate the user cost is central to decisions about fishery management, and can give direction to empirical work. In particular, we need to estimate how the value of recreational fishing responds to changing stock densities.

The Household Production Function

The value of fish allocated to the recreational sector can be determined from the recreationist's net benefit function as it depends

---

Kenneth McConnell is an associate professor in the Department of Agricultural and Resource Economics, University of Maryland.

Contribution Number 1879 of the Rhode Island Agricultural Experiment Station. This paper was based on data gathered as part of a three-year study on recreational fishing funded by the National Marine Fisheries Service and the University of Rhode Island Sea Grant Program. The author appreciates the help of Nancy Bockstael whose ideas formed an integral part of this paper. He also wishes to thank Bill Ralph for help in all stages, and Jon Sutinen and T. J. Tyrell for valuable comments.

upon catch rates and trips.[1] To estimate this function, it is useful to adopt the household production function framework:

$$(1) \qquad x = x(\mathbf{w}_1),$$

where x is trips and $\mathbf{w}_1$ are inputs used to produce x, for example days, miles traveled.

$$(2) \qquad q = q(\mathbf{w}_2, S, \mathbf{a}),$$

where q is fish caught per trip, and $\mathbf{w}_2$ are inputs used to catch more fish per trip; for example, bait, time per trip, etc., S is the stock density of fish, and $\mathbf{a}$ is a set of attributes peculiar to the individual which affects production technology. S is a public input in the sense that it enters all anglers' production functions.

An individual's choices of trips and catch per trip can be viewed as if it were the result of a two-step maximization process. In the first step the individual minimizes $\mathbf{p}_1\mathbf{w}_1 + \mathbf{p}_2\mathbf{w}_2$, the cost of achieving x and q, where $\mathbf{p}_i$ is the price vector for inputs $\mathbf{w}_i$. The result is a cost function which depends on $\mathbf{p}_i$, x, q, $\mathbf{a}$, and S. It is assumed that S and $\mathbf{p}_i$ do not vary systematically across individuals. In the second step the user maximizes utility subject to costs of the consumption bundle not exceeding income, I.

The equilibrium conditions for this two-step process are:

$$(3) \qquad \begin{cases} f_x(x,q,I) = MC_x(x,q,\mathbf{a}) \\ f_q(x,q,I) = MC_q(x,q,\mathbf{a}), \end{cases}$$

where $f_x(\cdot)$ and $f_q(\cdot)$ are the marginal value functions for x and q, and $MC_x(\cdot)$ and $MC_q(\cdot)$ are the marginal cost functions for x and q. If the individual cannot adjust his catch rate, then $\partial q/\partial \mathbf{w}_2 \equiv 0$, and catch rates may be considered exogenous. Then (3) reduces to $f_x(x,q,I) = MC_x(x)$ which is simply the travel cost method if $MC_x(x)$ is independent of x.

In the following two sections applications of the travel cost and household production function approaches to data gathered from a survey of marine recreational fishing in Rhode Island are presented. The example pertains to fishing for winter flounder. As the reader will discern, the estimates presented are not conclusive. It is perhaps most useful to consider these empirical results as an example of how one might apply the two approaches.

The version of the household production function presented is based on the idea that fishermen can increase their catch rate per trip by spending more on bait and equipment. We assume, for a given individual, that the catch rate does not vary systematically with trips (i.e., the catch rate is constant across trips per year, except for a random component). The cost of increasing trips depends on the catch rate per trip. Thus, the higher the catch rate, the higher the marginal cost of a trip. Likewise, the marginal cost of the catch rate increases if there are more trips. Let t be the constant travel cost per trip, and let c_q be the constant cost of catching a fish. Then total costs per year are given by:

$$(4) \qquad C(x,q) = xt + xqc_q.$$

Observe that

$$\begin{aligned} \partial C/\partial x &= t + c_q q = MC_x(q) \\ \partial C/\partial q &= xc_q = MC_q(x). \end{aligned}$$

Hence, though the marginal cost of x is independent of x, it depends on q, and similarly for the marginal cost of q.

To complete the system, we assume that the demand functions can be approximated by linear forms, so that (3) can be written:

$$(5) \qquad \begin{cases} x = a_0 + a_1 p_x + a_2 p_q + a_3 z_1 + \theta_1 \\ q = b_0 + b_1 p_x + b_2 p_q + b_3 z_2 + \theta_2, \end{cases}$$

where the z_j are exogenous variables and θ_j are disturbances. Here p_q and p_x are the equilibrium marginal costs and marginal values of x and q. Substituting the marginal costs as given in (4) for p_x and p_q, we have

$$(6) \qquad \begin{cases} x = a_0 + a_1(t + qc_q) + a_2(xc_q) + a_3 z_1 + \theta_1 \\ q = b_0 + b_1(t + qc_q) + b_2(xc_q) + b_3 z_2 + \theta_2. \end{cases}$$

This system can be estimated by nonlinear two stage least squares (Kelejian), though the efficiency can be improved by using nonlinear 3SLS.

To compute social value from (5) and (4), we solve for the marginal values as a function of x and q. Suppressing the exogenous variables and the disturbances into the constant term and solving (5) for p_x and p_q, we have:

$$(7) \qquad \begin{bmatrix} p_x \\ p_q \end{bmatrix} = \begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \end{bmatrix}^{-1} \begin{bmatrix} x - a_0 \\ q - b_0 \end{bmatrix} = \begin{bmatrix} \gamma_0 \\ \beta_0 \end{bmatrix} + \begin{bmatrix} \gamma_1 & \gamma_2 \\ \gamma_2 & \beta_2 \end{bmatrix} \begin{bmatrix} x \\ q \end{bmatrix}.$$

By assuming that $\partial x/\partial p_q = \partial q/\partial p_x (b_1 = a_2)$,

[1] This section is an application of the ideas on the household production function presented in Bockstael and McConnell.

we can write the total value associated with x and q as a line integral from (0,0) to (x^*,q^*) (Burt and Brewer). Let this path be denoted Q. Then

$$(8)\ \text{Total value} = \int_Q f_x(x,q)dx + f_q(x,q)dq.$$

The net social value is given by the line integral

$$(9)\ \text{Net Value} = \int_Q [f_x(x,q) - MC_x(q)]dx + [f_q(x,q) - MC_q(x)]dq.$$

Symmetry is assured by definition in the cost function, but it must be imposed on the demand function. Imposing symmetry is equivalent to assuming that the income elasticities are equal for trips and catch rate.[2] This approximation we assume to hold locally.

Symmetry lets us express benefits as a path-independent line integral. Thus,

$$(10)\ \text{Net value} = \gamma_0 x + \gamma_1 x^2 + 2\gamma_2 xq + \beta_0 q + \beta_2 q^2 - tx - xqc_q.$$

For estimation purposes, (6) is rewritten with observation indexes

$$(11)\ \begin{cases} x_i = a_0 + a_1(t_i + c_{qi}q_i) \\ q_i = b_0 + b_1(t_i + c_{qi}q_i) \end{cases} \begin{aligned} &+ a_2(x_i c_{qi}) + a_3 z_{1i} + \theta_{1i} \\ &+ b_2(x_i c_{qi}) + b_3 z_{2i} + \theta_{2i}. \end{aligned}$$

The exogenous variables are z_1, z_2, t, and c_q. The nonlinear 2SLS procedure calls for estimating $t + c_q q$ and xc_q as polynomial functions of the exogenous variables in the first stage; in the second stage the predicted values of $t + c_q q$ and xc_q are used as instruments on the right hand side of (11). In the application here, z_1 is years of experience fishing and z_2 is the number of rod and reel combinations owned.

Table 1 presents preliminary results of the estimation procedure. These results are suggestive rather than final.[3] The equations were estimated with only fifty-six observations, perhaps accounting for the low t-values. More efficiency could also be achieved by accounting for the correlation between errors for the two equations. Consumer's surplus was computed on the basis of mean values of independent variables from equation (10). For a representative fisherman seeking winter flounder, consumer's surplus was computed to be $515.

The Travel Cost Approach

An alternative to the household production function is to assume that anglers cannot vary their catch rates. The result is a single equation system where the catch rate is exogenous. However, it is still an argument of the demand function because individual attributes such as rods and reels make catch rates vary across individuals. To use the travel cost approach we estimate with OLS

$$(12)\quad x_i = r_0 + r_1 t_i + r_2 q_i + r_3 E_i + \epsilon_i$$

where t_i is the cost of taking another trip, q_i is the catch per trip, E_i is the experience of angler in number of years fished, and ϵ_i is the random error term. This specification is fairly close to the spirit of the one given in table 1. The OLS results for equation (12) are

$$(13)\quad x_i = 7.1 - \underset{(2.58)}{.085t_i} + \underset{(.14)}{.015q_i} + \underset{(.42)}{.012E_i} \qquad \bar{R}^2 = .11 \quad n = 56,$$

where t-statistics are in parentheses. Obviously this equation leaves something to be desired in terms of explanatory power and significance of variables. It is worth noting that r_1 changed little with specifications involving different independent variables.

Consumer's surplus in the single equation case is computed as the area under the demand curve and above the cost line. For mean values of independent variables, consumer's surplus is $233. Although equation (13) is statistically weak, the estimate of consumer's surplus is robust because of the stability of the slope of the demand curve for specifications with other independent variables.

In addition to substantial uncertainty about coefficients of the equations, there are two reasons why the household production function estimates more consumer's surplus. First, the quality variable is complementary to trips, and to the extent that cost of quality and the

[2] Testing this assumption is quite difficult. Estimates of the coefficients on income variables in trip demand equations tend to be negative or insignificant and are biased because the cost of time is excluded from the price variable and is highly correlated with income. Empirical work from fertility studies suggests that the income elasticity for the quality variable is a good deal higher than for the quantity variable.

[3] A serious difficulty with these estimates is the omission of the cost of substitutes. All anglers come from Connecticut, Massachusetts, or Rhode Island, and they tend to have the same kinds of nonfishing substitutes available to them. However, substitution from one species to another is quite likely and very difficult to capture empirically. The ability to substitute among species implies that the estimates of net benefits presented here are biased upward.

Table 1. Preliminary Results

	Variable				
Equation	Constant	Marginal Cost of Trips	Marginal Cost of Catch Rate	Experience	Rods and Reels Owned
Trips	7.68	−.117	−.0087	.015	—
		(2.84)[a]	(.61)	(.57)	
Catch rate	2.39	−.0087	−.025	—	.628
		(.61)	(1.75)		(6.2)

[a] *t*-statistics in parentheses. Results based on fifty-six interviews of fishing for winter flounder in Rhode Island.

cost of trips are positively correlated, omitting the cost of quality will result in a downward bias for consumers' surplus. (This result is the converse of Burt and Brewer's finding that value estimate will be biased downward if relevant substitutes are omitted [p. 819].) If an individual can effectively choose quality as well as trips, then the mythical perfectly discriminating monopolist can extract rent from him in two dimensions of choice.

Results such as presented here can be used for policy by measuring the change in consumers' surplus induced by changes in the density or availability of fish stocks. For the single equation case we need to know the relationship between fish stock densities and catch rates (q). Then the marginal value of a one period change in the stock of fish can be computed by taking the product of the marginal value of the catch rate and the Δcatch rate/Δfish stock. Conceptually, this task is relatively simple. It is even reasonable to imagine that one could measure the relationship between densities and catch rates (see Stevens, for example). However, equation (13) is too weak empirically to justify such computations.

The household production framework can be used for policy analysis if we know the relationship between the cost of catching another fish (c_q) and fish stock density. Then the marginal value of a one period change in fish stock density is the product of Δc_q/Δfish stock and the change in consumer's surplus induced by changes in c_q. It is possible to design an experiment to show how c_q (or other costs) might change as the density of fish stocks change. However, no such effort has been attempted for recreational fisheries because it requires time series data on stock densities in particular areas as well as detailed information on recreational fishing over time.

Evaluation

The previous section has shown that there are substantial benefits from marine recreational fishing. Regardless of our measurement technique, we know that marine anglers receive benefits for the right to fish, and that those benefits increase as they catch more fish. The evidence at this time is by no means solid enough to compete with the commercial price of fish, but it is growing stronger (for example, we have similar evidence from Stevens and Talhelm).

With this evidence we should expect a willingness by marine policy makers to provide some portions of annual yields for recreational purposes. However, there is evidence that recreational fishing is still a second cousin to commercial fishing. A document reflecting the U.S. Department of Commerce's view of fisheries policy states "First priority has been placed on commercial fishing because of its importance" (U.S. Department of Commerce).

Economists have devoted substantial effort to devising methods of reflecting the social value of harvesting fish for recreational use. Yet many economists have found that policy makers see little connection between social benefits, as measured by economists, and resource allocation. Why are economists' measures of social welfare difficult to accept?

Many decision makers are basically mercantilists. They choose projects on the criterion of total expenditures, rather than net benefits. At the regional level, one can make some sense out of such a policy because it implies maximizing the region's balance of trade surplus. However, at the national level there is no legitimate reason for choosing on the basis of expenditures. Nevertheless, policy makers

are much more interested in estimates of expenditures than total value.

Decisions are made on the basis of the "do no direct harm" thesis (see Schultze, pp. 23–24). On that basis, the harm to commercial fishing interests from reducing their catch is obvious. The damage done to recreational fishermen, particularly when they do not support a substantial service sector, is not visible when one measures the damages by the change in the value of market transactions.

Economists have not measured the producers' surplus associated with harvesting fish commercially. Many fishermen are attracted to fishing as a way of life. A substantial, but unmeasured, social loss may occur when fishermen are forced to leave fishing for other occupations. The prospect of this loss by the fishermen generates much political pressure to ensure that commercial fishing effort is not reduced.

It is a difficult task to argue that society may be better off with a greater recreational harvest simply because sports anglers are willing to pay more for the additional fishing than commercial fishermen must be paid to compensate them for not fishing. It is difficult because we have few measures of changes in willingness to pay from changes in fishery policy. It is difficult because decision makers use many types of measures of welfare, and are as interested in the distribution of benefits as in Pareto-optimal changes.

What can economists do to improve resource allocation? The notion of Pareto optimality is central to economists' definition of improvement, but pure Pareto improvements are scarce. Hence we tend to deal with potential Pareto improvements, which may bring changes in the distribution of welfare. Economists can judge changes in resource allocation which induce welfare redistributions only by judging the relative importance of the welfare of different individuals. It is more plausible to suppose that economists can help improve resource allocation by describing as accurately and concisely as possible the implications of various management strategies. By describing the magnitude of recreational fishing in terms of catch and expenditures as well as consumers' surplus, economists can help ensure that marine recreational fishing receives fair treatment among policy makers conditioned to thinking only of commercial fishing.

References

Bockstael, Nancy E., and K. E. McConnell. "The Estimation and Use of the Household Production Function for Wildlife Recreation." University of Rhode Island Department of Resource Economics Staff Paper No. 15, Kingston, Rhode Island, October 1978.

Brown, Gardner M., John Charbonneau, and Michael Hay. "The Value of Wildlife Estimated by the Hedonic Approach." U.S. Department of Interior, Fish and Wildlife Service Work. Pap. No. 6, 1978.

Burt, Oscar R., and Durward Brewer. "Estimation of Net Social Benefits from Outdoor Recreation." *Econometrica* 39(1971):813–27.

Dwyer, John F., John R. Kelly, and M. D. Bowes. "Improved Procedures for Valuation of the Contribution of Recreation to National Economic Development." Water Resources Center Res. Rep. No. 128, University of Illinois, 1977.

Kelejian, Harry. "Two Stage Least Squares and Econometric Systems Linear in Parameters but Nonlinear in Endogenous Variables." *J. Amer. Statist. Assoc.* 66(1971):373–74.

McConnell, K. E., and J. G. Sutinen. "Bioeconomic Models of Marine Recreational Fishing." *J. Environ. Econ. Manage.* 6(1979):127–39.

Pollak, Robert A., and Michael Wachter. "The Relevance of the Household Production Function and its Implications for the Allocation of Time." *J. Polit. Econ.* 83(1975):255–77.

Schultze, Charles L. *The Public Use of Private Interest.* Washington, D.C.: The Brookings Institution, 1977.

Stevens, J. B. "Angler Success as a Quality Determinant of Sport Fishery Recreational Values." *Transactions Amer. Fisheries Soc.* 95(1966):357–62.

Talhelm, Daniel R. *Evaluation of the Demands for Michigan's Salmon and Steelhead Sport Fishery of 1970.* Lansing: Michigan Department of Natural Resources Fisheries Res. Rep. No. 1797, 1979.

U.S. Department of Commerce. *U.S. Ocean Policy in the 1970's: Status and Issues.* Washington, D.C., 1978.

Measuring Values of Extramarket Goods: Are Indirect Measures Biased?

Richard C. Bishop and Thomas A. Heberlein

The well-known travel cost method (TC) has been widely applied to outdoor recreation. A second approach has been referred to in the past as the Davis method, the questionnaire approach, and contingent valuation. It will here be termed hypothetical valuation (HV), because it involves creating a hypothetical situation designed to elicit willingness to pay for or willingness to accept compensation for a recreational or other extramarket good (or bad). TC and HV are termed "indirect methods," because they do not depend on the direct information about prices and quantities that economists would prefer to use where available to value goods and services.

A number of potential sources of bias in HV and TC have been discussed in the literature and we shall summarize these in the first section of the paper. When summed together, these potential problems are sufficient to justify considerable skepticism about the accuracy of resulting value estimates. Still, the question remains: How large an impact do these supposed sources of bias have in actual practice? In the second section of the paper we report the results of an experiment where TC and HV values were compared to values based on actual cash transactions. Though preliminary, the results of this experiment indicate that substantial biases exist in both TC and HV estimates.

Potential Sources of Bias

In TC, differences in travel and possibly other costs to recreationists at varying distances from the recreation site are used to infer how recreationists would behave if prices higher than the actual admission fee were charged. Thus, potential sources of bias exist if there are substantial differences in the recreationists' tastes and preferences, access to substitutes, and income levels at varying distances from the recreation site. It is fairly straightforward to control statistically for differences in income. Potential problems relating to tastes and substitute availability are much more difficult.

A particularly thorny problem in developing TC value estimates relates to time costs. It is clear that those who live farther from the recreation site in question not only incur larger transportation costs, but also expend more time in travel. What sort of price should be attached to this time? Several factors make this a complicated issue. Clearly the wage rate of adults overestimates what they could earn from second jobs. Furthermore, in opportunity cost terms, if people were not traveling to the recreation site most would probably be engaged in other leisure time activities rather than working. What is leisure time in the next best recreational activity worth? Also, how to value time of children and adolescent participants is not well understood. To make matters even more complex it is not inconceivable that travel to some recreation sites may actually add to the benefits rather than the costs, as when the route is a scenic one. Cesario has suggested that time be valued at between one-fourth and one-half the wage rate. While this is a beginning, it must be considered as a very crude adjustment since it is based on urban transportation studies and offers little guidance as to the exact figure to be used. As we shall see below, whether a factor of one-fourth or one-half is used can make a substantial difference in the value estimates.

TC requires that recreationists treat travel expenditures as equivalent to admission costs, yet this is a questionable assumption which no one has examined empirically. Travel costs represent an aggregation of many smaller costs, some of which (e.g., tire wear) may not be obvious to the recreationist and which are not

Richard C. Bishop and Thomas A. Herberlein are associate professors of agricultural economics and rural sociology, respectively, at the University of Wisconsin-Madison.

The research was supported by the College of Agricultural and Life Sciences, University of Wisconsin, and by Resources for the Future, the Wildlife Management Institute, and the University of Wisconsin Graduate School.

actually imposed on the recreationists at the time when the recreation is demanded. Admission fees are paid immediately, usually in cash. Particularly in a world of satisficing, travel costs may not be perceived as equivalent to admission fees.

Still other potential problems with TC techniques need to be noted. One stems from the fact that increases in density which recreationists label as crowding may affect quality. A travel cost demand curve implicitly assumes that recreational quality remains constant over the range from zero use to full use at the going admission fee. Thus, it may completely neglect changes in quality as quantity declines along the demand curve. Also, no satisfactory method has yet been devised to handle multiple-purpose trips (e.g., recreation plus work) or multiple-site trips (e.g., vacations involving several stops).

Because of these potential biases and because TC techniques are not applicable to recreational activities involving limited travel (e.g., backyard birdwatching) and many nonrecreational extramarket goods (e.g., air quality; public health programs), HV has evolved as a major alternative method of valuing extramarket commodities. Unfortunately, HV also has major potential sources of bias.

Hypothetical Valuation

Perhaps the source of bias that has most dominated the literature is gamesmanship. People who are asked hypothetically what they would be willing to pay for extramarket goods may recognize two different incentives to distort their responses. Perceiving that they will not actually have to pay and that their responses may influence the supply of an extramarket good or bad, people may respond in ways that are more indicative of what they would like to see done than how they would behave in an actual market. On the other hand, if people believe (correctly or incorrectly) that their responses will influence actual fees they may be more concerned about keeping their fees low than revealing their true values to the investigator. Similar thoughts apply if the HV measure is willingness to accept compensation (willingness to sell) rather than willingness to pay.

Furthermore, the hypothetical nature of the transactions may not be at all indicative of how people would behave in an actual market even if gamesmanship is not a major problem. When people buy things in a market, they may go through weeks or months of considering the alternatives. The process will often involve consultations with friends and may also involve professionals such as lawyers or bankers. It may also entail shopping around for the best deal on the product in question. And, for the majority of items in the consumer's budget, there is a whole history of past experience in the market to base the decision on. All this is markedly different than spending an hour or two at most with a mail survey or a personal interviwer attempting to discern how one might behave in a market for a commodity for which one has never actually paid more than a nominal fee.

Numerous other potential problems exist. Like TC, HV measures relate only to the status quo of the good whereas quality may change along the demand curve as the impact of density on recreational quality is felt. All the problems associated with surveys and interviews also may arise including the necessity of obtaining an adequate response rate, interviewer bias, and variations in responses depending on the construction of individual questions and the overall survey instrument.

Furthermore, while economists have been more or less cognizant of the potential pitfalls of HV discussed so far, they have not given much attention to a whole literature in social psychology which is also rather discouraging about HV's prospects for success. In a classic study from that field completed in the early 1930s, La Piere wrote to 251 restaurants, cafes, hotels, autocamps, and tourist homes asking the hypothetical question: "Will you accept members of the Chinese race as guests in your establishment?" Of the 128 that replied, 91% said no, 9% said they were uncertain or that it depended on the circumstances, and only one said yes. However, prior to mailing the letter, all 251 of the establishments had been visited by a Chinese guest and at only one was service refused. La Piere's study was followed by a host of others examining the relationships between attitudes and behavior. In a review published in 1976 of 150 such studies, Schuman and Johnson (p. 168) concluded that the correlations between attitudes and actual behavior are usually so low that they will not ". . . support the *substitution* of measured attitude for behavior . . . ." In other words, it may not be safe to assume, as economists applying HV techniques do, that what people say is what they would actually do.

As a matter of fact, there is some evidence that people do not even report their past behavior very well. For example, out of 131 people surveyed in one study who had been hospitalized during the preceding twelve months, 42% did not report it when interviewed (Cannell, Fisher, and Bakker). Parry and Crossley found that people overreport contributions to the Community Chest by 40% and voter registration by 25%. If people sometimes fail to report accurately what they have done in the recent past, it is a big step to assume, as we do in HV, that they can adequately predict and report how they would behave if a market for an extramarket commodity were created.

Our intention is not to argue that all answers to hypothetical questions will be inaccurate. Success in predicting many election results would be a counter example. Still, research on both attitude-behavior relationships and recall raise very serious questions about the validity of HV results.

But How Serious Are the Biases?

While all these potential sources of bias in both TC and HV exist, by themselves they are not conclusive. Perhaps their impact is negligible or in total they counterbalance each other. What is needed is empirical research to assess the extent of the biases in practice.

Previously published empirical results are for the most part encouraging. Studies by Bohm, Scherr and Babb, and Smith tend to indicate that fears among economists relating to gamesmanship are exaggerated. Furthermore, Bohm's results indicate that HV measures of willingness to pay may not be far from the mark. In the next section we will report the results of our own experiment, results which are not nearly so encouraging.

Results of the Experiment

Space constraints will not permit a thorough description of the experiment and how the results were arrived at. Only a summary will be presented here and the reader interested in a more thorough treatment is referred to an additional paper by Bishop and Heberlein.

The extramarket commodity that served as the subject of our study was 1978 early season goose hunting permits for the Horicon Zone of East Central Wisconsin. Nearly 14,000 such permits were issued and each entitled a hunter to take at most one goose from a well-defined area during the period 1 October through 15 October 1978. The hunters who were issued these permits fell into two groups. One group had applied for the early season as its first choice and automatically received a permit. The other hunters were allocated to the early season as their second choice, having lost in a lottery for middle season permits or applied for a middle season permit after the deadline.

Three entirely separate samples of goose hunters were drawn at random. The first consisted of 237 hunters who received actual cash offers for their permits. The offers were conveyed by mail along with checks ranging between $1 and $200 with instructions that each hunter should return either the check or his or her early season permit. A second sample (containing 353 hunters) received mail questionnaires specifically designed to develop HV measures of the value of its permits. A third (300 hunters) received questionnaires designed to estimate a travel cost demand curve for early season hunting.

The experiment itself was completed with response rates to all three surveys (recipients of the actual cash offers were surveyed after the early season) in the acceptable range of at least 80%. Comparison of the three samples using a one-tailed difference of proportions test on socioeconomic characteristics, commitment to hunting, past goose hunting experience and the like showed no intersample differences sufficient to interfere with comparison of the results across the samples.

Analysis of the results is still in progress, but our preliminary estimates are summarized in table 1. While our final results may vary somewhat in terms of absolute magnitudes, the data are sufficiently clear to justify confidence in our qualitative conclusions.

Responses to our actual cash offers yielded total consumer surplus associated with 1978 early season goose hunting permits of $800,000 for all hunters combined or $63 per permit. This estimate is a bit conservative since it assumes a maximum value per permit of $200 while both the econometric model and the data indicate that 10 to 12% of the hunters would not have sold at $200.

The actual willingness to sell figure is most easily compared with the HV measure of willingness to sell which turns out to be 60% larger at $101 per permit. This estimate is also based on a maximum value of $200 per permit. In

Table 1. Summary of Results

	Total Consumer Surplus	Surplus per Permit
	--------- $ ---------	
Actual cash offers	880,000	63
Hypothetical offers		
Willingness to sell	1,411,000	101
Willingness to pay	293,000	21
Travel cost estimates		
Model 1 (time value = 0)	159,000	11
Model 2 (time value = ¼ median income rate)	387,000	28
Model 3 (time value = ½ median income rate)	636,000	45

this case, the model predicted that 35% of the hunters would require offers of more than $200 before they would agree to sell their permits in hypothetical transactions. Thus, had the models been truncated at a higher figure the difference between willingness to sell measured using actual money and measured using hypothetical dollars would have been even more pronounced.

Comparisons of actual willingness to sell with hypothetical willingness to pay and the travel cost values are clouded by the well-known theoretical arguments relating to various measures of consumer surplus. However, following Willig, we would argue that for the range of values we are discussing here ($1–$200) and given any reasonable value for the income elasticity of demand for goose hunting permits, willingness to pay, and willingness to accept compensation should be quite close together. If so, then we could take $63 as being roughly the average willingness to pay of goose hunters for early season permits.

Referring again to table 1, it turns out that our HV measure of willingness to pay falls far short of $63 at only $21 per permit. The table also gives three TC values of willingness to pay based on three different assumptions about the value of time. Even using what the literature would indicate is a relatively liberal time value of one-half the income rate, the travel cost estimate averages only $45, 29% below the benchmark figure of $63.

Conclusions

We must be careful at this point to avoid sweeping conclusions based on a single experiment. Our results may not be able to be generalized to other situations. Furthermore, although the market we created for goose permits used real money, it was still highly artificial and may include biases of its own. Still, the results summarized here must be interpreted as supporting the hypothesis that the sources of bias listed above do have significant impacts on HV and TC values for recreation and other extramarket goods. Had we attempted to value goose hunting permits using an HV measure of willingness to sell, a substantial overestimate would have been obtained. If we had used HV willingness to pay or a TC measure of demand we would have apparently fallen substantially short of the true value of willingness to pay.

While a full set of conclusions from our study must come after additional analysis, some tentative conclusions are evolving which will have important implications for future recreation economic studies. First, there has been a tendency to view HV willingness to pay as more or less accurate and HV willingness to sell as badly distorted. Our results suggest that both measures are biased, but in opposite directions. It appears that HV willingness to pay should be considered a lower bound and HV willingness to sell, an upper bound. Secondly, our results support those who have voiced concerns about adequately accounting for time costs in TC studies. Differences in tastes and the availability of substitutes may also be a significant source of bias here.

Finally, and on a more general level, we would suggest that recreation economics has a long way to go before it can claim accuracy comparable to analyses of market phenomena. Much more research is needed to further develop and refine both TC and HV measures. To the extent possible, this should involve experiments like the one reported here. Furthermore, we hope that our results will encourage the discovery of new, improved approaches to valuing extramarket goods of all kinds. Such research is essential if economists are to help society recognize the contribution of extramarket goods to the overall level of economic well-being and facilitate sound assessments of the trade-offs between market and extramarket goods and services.

References

Bishop, R. C., and T. A. Heberlein. "Travel Cost and Hypothetical Valuation of Outdoor Recreation:

Comparisons with an Artificial Market." Mimeographed. Madison: University of Wisconsin, 1979.

Bohm, P. "Estimating the Demand for Public Goods: An Experiment." *Europ. Econ. Rev.* 3(1972):111–30.

Cannell, C. F., G. Fisher, and T. Bakker. "Comparison of Hospitalization Reporting in Three Survey Procedures." *Vital and Health Statistics*. Washington, D.C.: U.S. Dep. of Health, Education, and Welfare, Public Health Service Ser. 2, no. 8, 1961.

Cesario, F. J. "Value of Time in Recreation Studies." *Land Econ.* 52(1976):32–41.

La Piere, R. T. "Attitudes vs. Actions." *Social Forces* 13(1934):230–37.

Parry, Hugh J., and Helen M. Crossley. "Validity of Responses to Survey Questions." *Public Opinion Quart.* 14(1950):61–80.

Schuman, H., and M. P. Johnson. "Attitudes and Behavior." *Ann. Rev. Sociol.* 2(1976):161–207.

Scherr, B. A., and E. M. Babb. "Pricing Public Goods: An Experiment with Two Proposed Pricing Systems." *Public Choice* 23(1975):35–53.

Smith, V. L. "The Principle of Unanimity and Voluntary Consent in Social Choice." *J. Polit. Econ.* 85(1977):1125–29.

Willig, R. D. "Consumer's Surplus without Apology." *Amer. Econ. Rev.* 66(1976):589–97.

Valuing Nonmarket Goods—Conceptual and Empirical Issues: Discussion

Sandra S. Batie and Leonard Shabman

A decade ago Stevens lamented that there remained the task of proving to economists and to noneconomists "that the measurement of recreational demand is not a naive empirical 'trick' " (p. 192). Freeman, McConnell, and Bishop and Heberlein have given excellent perspectives on the recent advancement of the state of the art for valuing nonmarket services such as recreation. However, it is our concern that despite this progress, economists' ability to provide the information most often requested by public decision makers still is not well developed. Also, we believe that a reason for the indifference of policy makers to economic analysis goes beyond problems of potential biases in survey responses or travel cost methodologies as discussed by Bishop and Heberlein or the reasons detailed by McConnell. Rather, economists have not established relative values for the policies and inputs over which agencies have control (e.g., habitat management and fish stocking), and instead have focused research efforts on establishing values for recreational services. Figure 1 can help illustrate our point with specific reference to recreational fishing. It depicts the relationship between public policies, recreational services, utility, and value.

McConnell's and Bishop and Heberlein's papers provide a good example of economists' tendencies to estimate the value of the recreational services rather that the variables which policy makers control. McConnell concentrated on the contribution of household inputs to the value of recreational services narrowly defined as trips or catch per trip. Incidentally, we note that he ignored (although in most cases consciously) other determinants of the value of fishing recreation such as substitute and complementary recreational opportunities (e.g., fishing for other marine species) and nonconsumptive recreational services as a joint product with fish catch (e.g., enjoyment of the outdoors). Omission of variables to represent these determinants are more likely to account for the unsatisfactory statistical results of McConnell's regression than is the reported caveat that there were only fifty-six observations. In contrast, Bishop and Heberlein's various value measures of the right to hunt geese are based upon a broader concept of the recreational service. Their findings can help us to improve value estimates of the right to goose hunt, but even so, resource managers are frequently more concerned with the value of an additional goose or increments to goose habitat. Bishop and Heberlein do not address the latter value. Our point is not to suggest these authors' work necessarily should encompass all the variables reflected in figure 1, but rather to suggest that collectively economists have paid too little attention to the physical production and transformation linkages between public policies and recreational values.

Unfortunately, many of the linkages which could help establish the value of alternative resource policies are not well understood. For example, one set of linkages that is not well defined are the "production functions" relating public policies to changes in resource based inputs and the transformation function to recreational services. McConnell states that "it is even reasonable to imagine that one could measure the relationship between densities and catch rates," but he does not elaborate. In his book where he expands on the concepts presented in his paper, Freeman states that "data on the relationship between biological productivity and water quality can be used to determine the increase in net physical yield [of fish], associated with the pollution control program" (p. 68), but does not state how this is to be done. Yet understanding, defining, and quantifying these inputs and linkages is important if economists are to provide economic values that assist public agencies' management of habitat and resource stocks. The lack of knowledge about such

Sandra S. Batie and Leonrd Shabman are associate professors in the Department of Agricultural Economics at Virginia Polytechnic Institute and State University.

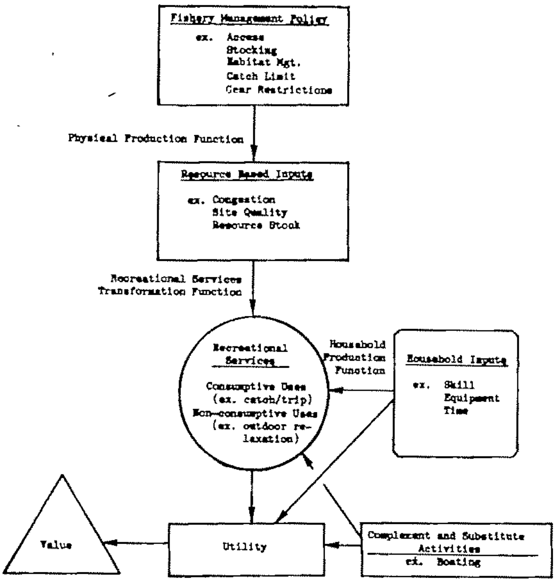


Figure 1. Determinants of recreational value of fishing

production and transformation functions is due, in part, to a lack of physical and biological data. Obviously, economists would be well advised to seek the assistance of biological and physical scientists, but we have done so infrequently.

Until more is known about these inputs and linkages, extreme caution must be used when attempting to impute the value of what is known to the value of that which is not. McConnell, for instance, suggests that "there are substantial benefits from marine recreational fishing" and that "with this evidence we should expect a willingness by marine policy makers at the national level to provide increasing portions of annual yields for recreational purposes." This statement suggests knowledge of the value of fish stocks and by imputation knowledge of the value of public policies which increase such stocks. This reasoning, however, if not used cautiously can be as erroneous as imputing all the value of a corn crop to only one of the inputs, say the corn picker or the corn sheller. Despite these quotes in the paper's conclusions, McConnell does appear to avoid this logical error in the body of the paper by focusing correctly on the role of fishing success as a recreation demand shifter and delineating the need to know the relationship between fish stock densities and catch rates for policy evaluation purposes, but admits that he cannot yet empirically calculate the measure. Given this, it is not surprising that public agencies are not receptive to economic arguments for reallocating fish from commercial to sports harvests when such arguments have not established the role of the fish per se to the value of the service.

These three papers well represent the "state of the art" in the area of value analysis of the recreational experience and of environmental amenities. Yet, there is considerable research remaining if economists are to provide the information necessary for informed public choice. It is our opinion that policy-directed research must focus upon estimating the value and functional relationships of variables that can be influenced by public policy as well as the type of research reported on by these papers.

References

Freeman, III, A. Myrick. *The Benefits of Environmental Improvement: Theory and Practice*. Baltimore, Md.: Johns Hopkins University Press for Resources for the Future, 1979.

Stevens, Joe. "Effects of Nonprice Variables upon Participation in Water-Oriented Outdoor Recreation: Comment." *Amer. J. Agr. Econ.* 51(1969):192–3.

Editor's Note:
Oscar R. Burt, Montana State University, was a discussant for this session but did not present a paper for publication.

Small Farm Definition and Public Policy

Thomas A. Carlin and John Crecink

Even the most casual review of literature suggests that there are numerous definitions of small farm. Range in definitions varies from acres of land, units of livestock, value of farm products sold, days worked off-farm, level of farm income, to level of total family income (Lewis). Many authors combine two or more of these classifications to arrive at a more limited definition. Some authors even display wisdom by not attempting to define specifically what they mean by small farms. It becomes clear that the small farm is not precisely defined either within the agricultural research community or for the general public. As Wood recently pointed out, "Small becomes less a descriptive term than it is a philosophical one . . . . Policy objectives and small farm categories are interrelated, and they are identified on the basis of the concerns of interested parties or participants" (Wood).

Public discussion of small farm issues is also confounded by a lingering set of beliefs about farming—some of which may no longer be valid. These beliefs include:

(*a*) The economic performance of the farm establishment is an accurate reflection of the economic well-being of the farm family.

(*b*) Small farms are problems, while family farms have problems. Images of the family farm are inherently positive, while images of the small farm are inherently negative.

(*c*) Small farms are inherently inefficient, thus are poor users of resources.

(*d*) The relative vitality of a rural community is directly dependent on the vitality of the farming sector in and around that community.

Clearly, our individual response to small farm issues depends to some extent on our perceptions about agriculture and rural America.

An imprecise definition of "small farm" may serve the policy process quite well. Groups with somewhat divergent goals can unite in efforts to advance a "small farm" policy with a shared sense of satisfaction. But those who are responsible for implementing small farm policy (particularly if specific assistance programs are involved) must again face the issue of defining a small farm (for eligibility purposes). This problem is particularly acute for statisticians who must provide basic counts of the probable target population, for example. Vague or imprecise definitions are simply not amenable to efficient data collection, particularly in an era alive with concerns about respondent burden and privacy. Thus, we must come to grips with an acceptable small farm definition so that we can get on with the real work at hand—helping those small farm families eligible for assistance.

Attributes of a Good Definition

A desirable small farm definition should have an understood underlying conceptual basis. Frequently used definitions of small farm appear to be derived from two basic concepts. The first concept of small farm is that of a low volume business establishment (area A and B, fig. 1). The most notable definition of this type is farms producing less than $20,000 in gross farm products. Proponents of this type of definition are generally as concerned about issues such as increased concentration in agricultural production and marketing, dependence on capital intensive technology, use of harmful production practices, and land reform, as they are about other issues.

The second concept of a small farm is that of a farm operator or family having a low level of economic well-being (e.g., income) (areas B and C, fig. 1). The recent USDA small farm definition is an example of this type definition. The USDA definition includes all farm families (*a*) whose family net income from all sources (farm and nonfarm) is below the median nonmetropolitan income of the state, (*b*) who depend on farming for a significant though not necessarily a majority of their income, and (*c*) whose family members provide most of the labor and management. Proponents of this type definition generally are more concerned

Thomas A. Carlin and John Crecink are economists with the Economic Development Division, ESCS USDA.

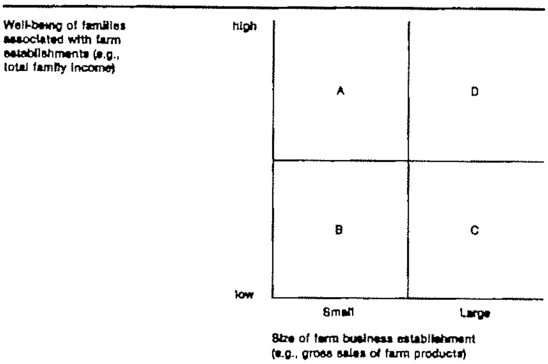


Figure 1. Conceptual bases for a small farm definition

about issues of limited resource farmers and farm poverty than about other types of issues.

Proponents of both types of definition are quick to eliminate certain types of farming activity from their respective focus. For example, they are particularly alienated by "hobby" farmers and others who are able to convert ordinary income into capital gains using special farm tax rules, thus sheltering nonfarm income. Thus, one attribute of "the optimal definition" (if such a definition should exist) would be to exclude the less desirable types. One caution, however: constraining the definition too much may reduce the absolute size of the target population so that political support for small farms (and assistance programs) may be reduced. (e.g., There would be broader support for a target group of 1.5 million than for one of 25,000.)

Debate over a small farm definition also can be minimized if the definition chosen, regardless of its conceptual basis, would include a relatively large common element (area B, fig. 1). This attribute would allow each interest group to identify subcomponents of the small farm population of particular concern and still identify with the coalition supporting the small farm movement.

The chosen definition should have other desirable attributes from a statistical perspective. The definition should be understood easily by all data users. The elements of the definition should be measurable. Most important, the definition should be workable—capable of being implemented using conventional statistical procedures. This, by the way, was one problem with the old definition of a farm—it was becoming impossible to develop a list frame for extremely small establishments. In addition, the definition must allow for feasible data collection and collation, within the constraints of existing budgets.

With the background in mind, this paper will look at three definitions of small farms which are under discussion, at least in Washington, D.C. The first definition will be farm families with a total family income below the median nonmetropolitan income of the region, consistent with the low income concept of small farm. The second and third definitions will be all families operating a farm business selling less than (*a*) $20,000 and (*b*) $40,000 in farm products, consistent with the small business establishment concept. Selected characteristics of families under these definitions will be examined with implications for public policy. Others have examined in detail the characteristics of farms selling less than $20,000 in farm products (Larson, Lewis). But, relatively little is known about the low income farm families, particularly characteristics of their farming operations.

Data

The data presented below are mainly from the 1975 Farm Production Expenditures Survey (FPES) conducted by the Statistical Reporting Service (now Economics, Statistics and Cooperative Services, U.S. Department of Agriculture). This was a national probability sample of approximately 5,700 farmers designed to obtain detailed data on farm production expenses. Information also was obtained on farm and off-farm income, farm assets, and occupation and age of the farm operator. This was the most readily available and most recent source of national data on attributes of farm operators and their farms at the time the paper was prepared.

The unique advantage of the FPES survey data is the ability to sort individual observations (families) by the alternative criteria for defining small farms. Currently, this advantage is not present in other data sources, particularly those which provide information on both the characteristics of the operator and family and attributes of the farming business.

The distribution of farms by value of agricultural products sold is skewed upwards in the FPES survey compared to the Census of Agriculture. For example, the proportion of farms with sales of $40,000 and over is larger in the FPES (36% of all farms) than in the census data (21% of all farms). Thus, distribu-

tion data used below are from the 1974 Census of Agriculture and the Current Population Survey (U.S. Department of Commerce 1974, 1977).

Some characteristics of operators within the lower sales classes derived from the FPES are consistent with census data (e.g., average age, occupation, and days worked off-farm by the farm operator; and median size farm). Median off-farm income appears to be consistent with Census of Agriculture estimates but considerably below USDA estimates. However, estimates of median net cash farm income from the FPES are troublesome, being substantially below those from other sources.[1] Other important attributes of the operator family, such as family size, race, and off-farm occupation, were not included in the FPES survey. No attempt was made to adjust the data presented below. Rather, attention should be concentrated on differences among the alternative small farm groups rather than on the absolute estimates themselves.

Results

Approximately 52% of all farm families have total family incomes below the median nonmetropolitan income for their region in 1975.[2] This low income group is smaller than those families operating a small business establishment; two-thirds (66%) operated farms selling less than $20,000 in farm products; about four-fifths (79%) operated farms selling less than $40,000 in farm products in 1974. Regardless of the definition used, small farmers are located throughout the United States with the major concentrations in the North Central and Southern regions (table 1). Relatively more low income farmers live in the North Central region, particularly the West North Central, than do operators of small businesses. This is due in part to the fact that Southern farm operators are more likely to have an off-farm job which raises total family income.

FPES data suggest that low income farm operators are more likely to have farming as their principal occupation than are operators of small farm businesses (table 2). On the average, low income farmers work fewer days off-farm, resulting in lower off-farm incomes. Total family income for low income operators is almost half that for operators of small farm businesses. Low income operators appear to have larger acreages than operators of small businesses. And low income operators have more invested in their farms than operators of farms producing less than $20,000 in sales.

There appears to be little difference in the operator age-distribution among the three small farm groups (table 2). And there appears to be little difference in the types of farming activities engaged in by low income farmers

[1] Net cash farm income excludes inventory adjustments, value of home-produced and consumed food, and the rental value of the farm dwelling. These items are typically included in other data sources.

[2] This estimate is from the Current Population Survey (U.S. Dep. Commerce 1977a). The estimate from the FPES was approximately 55%.

Table 1. Geographic Distribution of Small Farm Families under Alternative Definitions

Region/division	Families with Incomes below Median Nonmetro Income (1975)[a]	Families[b] Selling Farm Products of Less Than $20,000 (1974)	Families[b] Selling Farm Products of Less Than $40,000 (1974)
	(%)		
Northeast	6	5	5
New England	2	1	1
Middle Atlantic	4	4	4
North Central	42	37	41
East North Central	17	18	19
West North Central	25	19	22
South	43	49	44
South Atlantic	13	15	14
East South Central	15	18	15
West South Central	15	16	15
West	9	9	9
Mountain	5	4	4
Pacific	4	5	5

[a] U.S. Department of Commerce 1977b.
[b] U.S. Department of Commerce 1977a.

Table 2. Characteristics of All Farm Families, Low Income Families, and Families with a Small Farm Business, 1975

Characteristics	Unit	All Farm Families	Low-Income Farm Families	Families with Small Farm Business Gross Sales Less Than $20,000	$40,000
Farming principal occupation[a]	%	69	69	48	56
Working off-farm 100+ days	%	35	36	55	48
Median total family income	$	10,300	3,300	6,200	7,000
Median net farm income	$	2,900	2,000	2,400	4,400
Median off-farm income	$	3,600	3,300	7,600	5,600
Average age	Years	52	53	53	52
Under 35	%	12	12	12	12
35–64	%	73	66	66	68
65 and over	%	15	22	22	20
Median size farm	Acres	185	135	82	106
Median market value of farm assets	$(thou.)	232	142	91	121
Median net worth	$(thou.)	204	110	84	96
Type of farm[b]					
Small grain	%	10	9	7	8
Cotton/tobacco	%	2	2	3	3
Corn/soybean	%	27	24	20	23
Potato	%	1	—	—	—
Other field crop	%	1	1	—	—
Vegetable	%	3	2	2	2
Horticultural crops	%	7	21	27	23
Livestock, dairy, and general	%	39	41	41	41

Source: Special tabulations from the USDA *1975 Farm Production Expenditure Survey*.
[a] That occupation which operator spent the majority (50% or more) of his work time in 1975.
[b] Based on crop using the largest acreage in 1975.

and those operators of farms selling less than $20,000 and $40,000 in farm products.

About 70% of the low income farmers reported a loss in their farming operation in 1975 (table 3).[3] These farm families had higher average off-farm incomes than those farm families reporting farm profits. But even then, the majority had low off-farm incomes. Operators of small farm businesses were just as likely to have a farm loss in 1975 as low income farm families (table 4). But, small farm business operators reporting losses (75% and 66% of those reporting sales of less than $20,000 and $40,000, respectively) were much more likely to have higher off-farm incomes than their low income counterparts. To the extent that one associates high off-farm income and farm losses with "hobby" farming, it appears that the low income concept of small farm eliminates more "hobby" farmers from a small farm population.

[3] Forty-nine percent of the respondents to the FPES reported a loss on their farms in 1975. The Internal Revenue Service reported that 47% of all sole proprietorship farm businesses operated at a loss in 1975.

A large part of the similarity observed among many characteristics of the alternative small farm groups is due to the size of the common element (area B, fig. 1). The FPES data suggest that about three-fourths (76%) of all operators with farms selling less than $20,000 also had total family incomes below the nonmetro median income. About 71% of operators with farms selling less than $40,000 had total family incomes below the nonmetro median. These two groups constituted, respectively, 72% and 84% of the total low income group. While the FPES undoubtedly overstates the size of this common element because of the reported low farm incomes, the true overlap is most likely sizable. For example, similar tabulations from the 1973 Farm Family Living Expenditure Survey suggests that 62% of all operators with farms selling less than $20,000 in farm products had total family incomes below the nonmetro median for that year.

Relative to the two groups with small farm businesses (table 4), the common population (area B, fig. 1) is more dependent on farming,

Table 3. Characteristics of Low Income Farm Families, 1975

Characteristics	Unit	All Low Income Farm Families	Negative Farm Income	Positive Farm Income
Farming principal occupation[a]	%	68	60	87
Working off-farm 100+ days	%	36	44	17
Median total family income	$	3,300	2,500	6,100
Median net farm income	$	2,000	−3,700	3,300
Median off-farm income	$	3,300	5,100	700
None	%	27	21	40
Under 5,000	%	33	28	44
5,000–9,999	%	21	24	15
10,000 and over	%	19	27	1
Average age	Years	53	53	54
Under 35	%	12	12	11
35–64	%	66	66	66
65 and over	%	22	22	23
Median size farm	Acres	135	108	189
Median market value of farm assets	$(thou.)	142	123	176
Median net worth	$(thou.)	110	96	161
Type of farm[b]				
Small grain	%	9	8	10
Cotton/tobacco	%	2	2	4
Corn/soybean	%	24	21	30
Potato	%	—	—	—
Other field crop	%	1	1	1
Vegetable	%	2	3	2
Horticultural crops	%	21	26	9
Livestock, dairy, and general	%	41	39	44

Source: Special tabulations from the USDA *1975 Farm Production Expenditure Survey*.
[a] See footnote 1, table 2.
[b] See footnote 2, table 2.

working fewer days off-farm and having lower off-farm incomes (table 5). On the other hand, the common population is slightly older than the low income population and has smaller farms (acreages and value) (tables 3 and 5).

The trade-off groups between the two basic concepts of small farm are areas A and C in figure 1. Group A, higher income small farm business operators, appear to be middle-age (almost all between 35 and 64 years old) operators with relatively large off-farm incomes (most reported $10,000 or more), most of whom are not farmers by occupation. Group C, lower income families with larger farms, appear to be middle-age operators whose occupation is farming and who have lower off-farm incomes (most reported less than $5,000).

Implications

There are differences in general policy focus inherent in the two concepts of small farm. The low income definition focuses on individuals and families who have a commonly understood problem—moderate to low income. The implied objective is to undertake actions which improve their income (well-being) level. This objective flows naturally from the concept itself. While the small business concept focuses attention on certain farm establishments, it does not present a commonly understood problem. And the concept itself does not suggest a clear policy objective; rather, the policy objectives emerge from an understanding of population characteristics.

There appears to be some distinction between the populations included in the two concepts of small farm (besides those differences inherent in the concept itself). The above analysis suggests that low income farm operators are tied closer to farming (both by occupation and income) than are operators of small farm businesses. In other respects, there is very little difference in population characteristics between the two concepts. For example, regardless of the definitions considered above, small farmers are concentrated in the North Central and South, a fifth are aged and

Table 4. Characteristics of Farm Families with a Small Farm Business, 1975

		Selling Farm Products of					
		Less than $20,000			Less than $40,000		
Characteristics	Unit	All	Negative farm income	Positive farm income	All	Negative farm income	Positive farm income
Farming principal occupation[a]	%	48	40	72	56	51	80
Working off-farm 100+ days	%	55	59	41	48	59	26
Median total family income	$	6,200	5,900	7,100	7,000	5,200	9,600
Median net farm income	$	2,400	−2,700	2,400	4,400	−2,900	4,400
Median off-farm income	$	7,600	9,300	3,400	5,600	8,900	2,300
None	%	14	10	24	18	12	30
$1–4,999	%	26	22	38	27	22	37
5,000–9,999	%	20	21	18	19	20	15
10,000 and over	%	40	47	20	36	46	18
Average age	Years	53	52	55	52	52	53
Under 35	%	12	13	10	12	13	11
35–64	%	66	67	64	68	68	68
65 and over	%	22	20	26	20	19	21
Median size farm	Acres	82	66	132	106	74	175
Median market value of farm assets	$(thou.)	91	89	94	121	94	176
Median net worth	$(thou.)	84	82	90	96	86	137
Type of farm[b]							
Small grain	%	7	6	10	8	7	11
Cotton/tobacco	%	3	2	5	3	2	4
Corn/soybean	%	20	18	28	23	19	32
Potato	%	—	—	1	—	—	—
Other field crop	%	—	—	1	—	—	—
Vegetable	%	2	2	1	2	2	2
Horticultural crops	%	27	33	11	23	31	8
Livestock, dairy, and general	%	41	39	43	41	40	43

Source: Special tabulations from USDA *1975 Farm Production Expenditure Survey*.
[a] See footnote 1, table 2.
[b] See footnote 2, table 2.

perhaps reducing the intensity of their farming operations, and they are engaged in all types of farming. Regardless of the definition used, the small farm population appears to be heterogenous; no single major attribute emerges aside from income level and relative dependency on farming.

While the two concepts of small farms (low income and small business) elicit a different general policy focus, practical approaches to assisting small farmers may not differ. This is due to the fact that a large number of the same farm operators would be included in a small farm population under either concept. Regardless of the definition, programs to assist small farmers must be diverse in order to accommodate the heterogeneity of the population. Some small farmers can benefit most from programs to improve farm operations, others can benefit most from increased off-farm employment opportunities, and still others (e.g., the elderly) may benefit most from improved access to public assistance and social services. The exact combination depends almost entirely on the circumstances faced by the individual small farm family.

Perhaps any final decision on the proper concept of the small farm definition lies in the public's preference for the trade-off groups (groups A and C). This analysis suggests that the trade-off is between (*a*) operators of small farm businesses who are not farmers by occupation having relatively high off-farm incomes versus (*b*) full-time farmers operating larger farms but having problems making a satisfactory income. Given the public's apparent lack of social concern for hobby farmers, the low income concept appears to have a distinct advantage over the small business establishment concept; low income farmers are less likely to view farming as a hobby. Yet, there is enough diversity in the low income farm population to accommodate the concerns of those who are interested in issues typically associated with a small business concept.

A more detailed and accurate description of

Table 5. Characteristics of Low Income Farm Families Operating a Small Farm Business, 1975

		Selling Farm Products of					
		Less than $20,000			Less than $40,000		
Characteristics	Unit	All	Negative farm income	Positive farm income	All	Negative farm income	Positive farm income
Farming principal occupation[a]	%	58	50	83	63	53	88
Working off-farm 100+ days	%	45	52	22	40	49	18
Median total family income	$	3,900	3,200	5,100	3,900	2,900	5,800
Median net farm income	$	2,000	−2,000	2,000	2,800	−2,200	2,800
Median off-farm income	$	4,800	6,300	1,900	4,100	6,000	1,100
None	%	18	14	31	22	16	37
$1–4,999	%	33	29	47	34	29	46
5,000–9,999	%	26	28	20	23	27	15
10,000 and over	%	23	29	2	21	28	2
Average age	Years	55	54	57	53	53	54
Under 35	%	11	12	9	12	12	10
35–64	%	62	63	59	64	64	63
65 and over	%	27	25	32	24	24	27
Median size farm	Acres	88	74	130	104	84	161
Median market value of farm assets	$(thou.)	85	84	89	95	90	132
Median net worth	$(thou.)	79	77	86	88	82	118
Type of farm[b]							
Small grain	%	7	7	10	8	7	10
Cotton/tobacco	%	3	2	6	2	2	4
Corn/soybean	%	20	18	26	22	20	28
Potato	%	—	—	—	—	—	—
Other field crop	%	1	—	1	1	—	1
Vegetable	%	2	2	2	2	2	1
Horticultural crops	%	27	32	12	24	30	9
Livestock, dairy, and general	%	40	39	43	41	39	46

Source: Special tabulations from USDA *1975 Farm Production Expenditure Survey.*
[a] See footnote 1, table 2.
[b] See footnote 2, table 2.

the low income farm population must await more extensive surveys. The 1979 Farm Finance Survey, a follow-on survey to the 1978 Census of Agriculture, appears to be particularly promising. ESCS will continue to explore low income farmer attributes using other data files. Those states with good data available can also extend insight into the attributes of low income farm families.

References

Larson, Donald K., and James A. Lewis. "Farm Profile." *Small-Farm Issues: Proceedings of the ESCS Small-Farm Workshop, May 1978,* pp. 10–30. USDA ESCS-60, Jul. 1979.

Lewis, James A. "Implications of Alternative Definitions of a Small Farm." *Toward a Federal Small Farms Policy.* Washington, D.C.: National Rural Center. NRC Rep. No. 9, 17 Nov. 1978.

U.S. Department of Agriculture. *1975 Farm Production Expenditure Survey,* special tabulations.

U.S. Department of Commerce, Bureau of the Census. *Money Income in 1975 of Families and Persons in the United States.* Curr. Pop. Rep. Series P-60, No. 105, 1977a.

———. *1974 Census of Agriculture: United States Summary and State Data,* vol. 1, part 51. Washington, D.C., Dec. 1977b.

U.S. Treasury Department, Internal Revenue Service. *Income—1975 Business Income Tax Returns.* Washington, D.C., 1978.

Wood, William W., Jr. "Role of Small Farms in American Agriculture and Rural Society." *Increasing Understanding of Public Problems and Policies—1978.* Oak Brook, Ill.: Farm Foundation, 1978.

Toward an Agenda for Small Farm Research

J. Patrick Madden and Heather Tischbein

Ever since the days of Thomas Jefferson, the expressed intent of the nation's agricultural policy has been to support family farms, particularly small, land-owning farms. Despite expressions of concern and support by both agriculturalists and statesmen, often the effect (if not the intent) of public policy has been to undermine the economic and political support structures of a system of agriculture and rural communities based on land-owning family farms. Recently a widening array of interested groups of citizens have begun to express alarm over the discrepancy between the avowed intent and the ultimate effect of public policy—that is, the failure of public policy to achieve the goal of supporting family-owned and operated farms.

Increased attention to the changing structure of agriculture has illumined the economic, political, sociological, and ecological ramifications of the trend toward fewer but larger farms (especially highly technical and capital-intensive farms) to policy makers, the private sector, philanthropic organizations, and the public. This increased awareness has created a climate in which the value of small-scale family farms is being reassessed and reaffirmed. Advocates for smaller-scale family farms cite a wide range of adverse social and ecological consequences of current trends in production and marketing and in changes in the structure of agriculture as a rationale for more strenuous political and economic support of smaller-scale family farms. In general, these concerns are characterized by a striving to understand the interrelationships between and among production practices, marketing systems, the structure of agriculture, and their impact on ecological and human well-being. For example:

(*a*) The social, ecological, and economic vitality and viability of rural and urban communities is directly related to patterns of ownership, control, use, and distribution of agricultural resources. As the number of farms in a community decreases and size increases, the resultant migration of displaced residents has aggravated social and economic problems such as unemployment, alienation, inadequate housing and health care, and deterioration of the economic base of both rural and urban communities.

(*b*) The specialization and increased uniformity of farming resulting from the adoption of the techniques of regional monocultural production has increased the vulnerability and reduced the adaptability of agriculture to natural disasters; to large-scale disease and insect attack; to short- and long-term disruptions and shortages of energy supplies for production, processing, transportation, and storage of agricultural products; to soil erosion and depletion of soil organic matter; to pollution and depletion of ground and surface water; and to contamination of the food chain through the misuse and abuse of toxic chemicals used in producing and processing of foodstuffs.

(*c*) The ownership and control of land and other agricultural resources plus marketing and distribution mechanisms is becoming increasingly concentrated in the hands of fewer and fewer individuals and/or corporations, a trend which, if carried to extremes, could have severe implications for the survival of the nation's economic and political institutions.

The questions related to the viability of small-family farms are most realistically framed in the context of (*a*) the overall structure of agriculture, (*b*) the complex set of interconnected causal factors that determine trends in the structure of agriculture, and (*c*) the likely impact of changing structural patterns on the larger society and the environment.

Within the context of the interrelationships

J. Patrick Madden is a professor of agricultural economics at Pennsylvania State University; Heather Tischbein is project manager of the National Rural Center's Small Farms Project.

The Pennsylvania State University Agricultural Experiment Station Journal Series No. 5812. Supported in part by P.S.U. Hatch Project 2327, National Rural Center, National Science Foundation, and five other sources listed herein. The opinions expressed in this paper are those of the authors, not the sponsors.

described above, four areas consistently emerge as priority concerns: (*a*) the declining quality of rural life; (*b*) the impoverishment of limited-resource farm families; (*c*) the human, social, and ecological elements of economic efficiency; and (*d*) the perils of the disappearing middle.

Declining Quality of Rural Life

The quality of life in rural communities deteriorates as the support for various services, schools, churches, and other institutions dries up—a frequent result of the depopulation associated with the demise of small- to moderate-scale family farms.

The sociological studies, such as those by Goldschmidt and Fujimoto (U.S. Congress, p. 1394–96) should be extended to a wide range of locations and types of rural community, to provide a more solid basis for understanding the relationship between changing structure of agriculture and community decline (Rodefeld et al.). This type of research should include systematic collection of longitudinal data at two or more points in time, so that changes in farm structure and quality of rural life can be observed and causal relationships estimated.

Impoverishment of Limited-Resource Farm Families

While the vast majority of small farm families have family incomes above the poverty line (due to off-farm income) (Emerson) many of the small farm families with limited resources could become more self-sufficient and could afford a more adequate level of living if ways were found to increase their incomes—either through improved farming practices, better marketing options, or increased off-farm earnings. The "trapped," or limited-resource, farmers are those who are in poverty because the quantity and/or productivity of their labor, management, land, and other capital is chronically low and often getting less. These families seem unable to enhance their incomes either by moving away or staying. Simply assuming or advocating "perfect resource mobility" is of no comfort to those who have few job skills, few years before retirement or interment, or an unalterable determination to stay put. And while these small farms may be numerically prevalent and durable, their plight is often miserable.

Increasing the income-earning options of these small farms is clearly in the national and local community interest and is a worthy social and humanitarian goal.

The rationale for helping these small farmers to increase their incomes is partly humanitarian and partly pragmatic—it may be less expensive than welfare payments. Research should determine the conditions and situations under which various program strategies may be cost-effective in improving the self-sufficiency of limited-resource small farmers.

The Human, Social, and Ecological Elements of Economic Efficiency

There exists a wide range of phenomena (e.g., use of certain chemical pesticides) which are deemed to be economically efficient according to short-term accounting of firm-level costs and returns. However, if the scope of accounting were broadened to include short- and long-term social and environmental costs and returns, then some of these same phenomena may not be judged to be "efficient." A major research effort is needed to reexamine the concept of economic efficiency in this broader context and to develop measures and theoretical frameworks within which the trade-offs between firm-level efficiency in the conventional sense versus various human, social, and ecological concerns logically and systematically can be entered into the calculations.

The Disappearing Middle

Schumacher, in his book *Small Is Beautiful*, coined the term "disappearing middle," in describing a trend toward bifurcation of technology: very small and primitive technology coexists with mass production technology, while intermediate technology vanishes. Concerned agriculturalists have suggested this phenomenon is occurring in American agriculture. Assuming no major changes in the market structure and the political system, the very large farms are here to stay, probably in increasing numbers, and almost certainly in increasing importance as a source of the Nation's food and fiber, because of their economic efficiency and/or their market power. The very small farms are also here to stay—those part-time and retirement places and little patches of ground on the hilltops and narrow valleys and in the irregular corners of the huge fields, areas that cannot be economically

farmed as a part of a large farming operation. Here the opportunity cost of the land and other resources is often very low, and the farmer or farm resident depends largely on income from an off-farm job or business rather than from the sale of crops and livestock. Other commercial producers of specialty crops and livestock for special and limited markets (roadside stands, local organic markets, etc.) seem to be a permanent part of American agriculture. Still others are the limited-resource farms.

The very large farms are in no danger of disappearing, nor are the small farms whose families are either trapped in impoverished farming or have comfortable incomes from off-farm sources. However, the plight and prospects for the small- to moderate-sized farm that supports a farm family at a level considered "decent" by modern standards, with little or no help from off-farm jobs or other sources of outside income is much less certain. The need for preservation of this middle sector, of small- to moderate-sized family farms seems to be a central value judgment underlying much of the current concern for what is loosely termed the "small farm." Many observers are convinced that society needs to retain the flexibility of keeping options open, options which will disappear permanently if the middle sector of family farms is totally replaced by huge farming operations. Frequently, concern is voiced regarding the need to prevent an irrevocable concentration of farmland in the hands of a few investors—particularly speculators or others who have little concern for the husbandry of the soil or for enhancing the quality of life in rural communities.

Much of the current confusion and dissention related to small farms is the result of an overly simplistic view, implicitly thinking that all "small farms" are alike and that the social and economic or humanitarian rationale is equally compelling for all segments of the small farm sector. Clearly this is not true. More and better research is needed to clarify the issues. A priority in this area is developing a meaningful typology of small farms, indicating distinctly different kinds of small farms in terms of their resource endowments (land, labor, etc.), aspirations, sources of income, and other causal and descriptive factors that interact to determine their long-term survival and their potential for earning a decent level of income (Tweeten et al.).

Widely divergent views abound concerning research related to small farms. Some contend that all research, public and private, is stacked against the small- to moderate-scale family farm, in favor of huge corporate operations. Others contend that all, or virtually all research is "size-neutral," equally benefiting all farms regardless of size. Further, those in government who determine the budgets and the emphasis of research in various public agencies and educational institutions express no interest, or express outright hostility, toward the idea of increasing the level of research activity directly relevant to small farms (U.S. Congress). Other somewhat more sympathetic officials have indicated in personal conversations that if a comprehensive and well-documented research agenda were developed, then, and only then, would adequate research funds be forthcoming. It is primarily in response to statements of the latter kind that a national project on small farms research and policy was initiated by the National Rural Center in 1976.

The NRC Small Farms Project

The National Rural Center (NRC) is a private, nonprofit corporation, established to develop policy alternatives and to provide information which can help rural people improve the quality of life in their communities. A central value judgment underlying NRC's philosophy is that the goal of government ought to be to increase the options people have for a decent life in whatever kind of community they choose to live—rural, urban, or suburban. Because small-scale farming can provide an important option for earning income, and because, despite the predictions of many experts, a large number of people (many of whom, in some sections of the country, are minorities) wish to exercise that option, NRC selected small farm issues as a major policy development effort.

The project is organized into three phases, with the information brought together in each phase providing direction for subsequent phases. The work of each phase is reviewed at a conference whose participants include small farm operators, researchers, policy makers, and representatives from public and special interest groups.

The task in Phase I was to agree on a definition of small farm family and to identify barriers which hinder these families from increas-

ing on-farm income. In Phase II, issue groups reviewed the existing knowledge on each of those barriers, to determine on which issues there is adequate information, and which issues deserve additional research. The output of Phase II is a series of state-of-the-arts review papers, including preliminary discussions leading toward an agenda of research and demonstration projects. The goal of Phase III is to develop a set of federal policy recommendations based on the findings of Phase II. At the conclusion of the third phase, NRC, with the assistance of a wide range of individuals and interest groups, will recommend a federal small-farms program consisting of a research agenda, an agenda of demonstration projects, and policy alternatives.

Phase I was funded by the National Rural Center, Ford Foundation, Farm Foundation, and U.S. Department of Agriculture (USDA). Phase II was funded in part by grants from the Appalachian Regional Commission, the National Science Foundation, the Farm Foundation, the U.S. Department of Agriculture, the Community Services Administration, and the Rockefeller Brothers Fund. Funding for Phase III is in the development stage.

Phase I

The Phase I workshop, was held 16–18 October 1977, at Winrock International Livestock Education and Training Center, Morrilton, Arkansas. Forty individuals from around the nation and with varied backgrounds came together primarily to discuss the questions of small farm definition and barriers which hinder small farm families from increasing on-farm income.

The working definition of small farm family adopted at the conference contains three provisions: (*a*) The family or individual must rely on farm income for a substantial share of their livelihood. Hobby farms of the wealthy are excluded; (*b*) The operating family or individual must manage or control the farm business and must contribute the majority of the farm labor (except in peak seasons); and (*c*) The family or individual income must be moderate or less. The target "moderate" income level (including income from all sources) is the national median, currently about $18,000.[1] In addition, it was agreed that, within the working concept, priority for policy and research should be given to those who have low incomes, desire to become small farm families as defined above, and experience infrastructure barriers to full participation in our economic system.

The lists of barriers to increasing on-farm income developed by separate task groups of the conference were categorized into six general areas. These areas form the basis of Phase II of the NRC Small Farms Research Agenda and Policy Project. The areas identified by participants at Winrock were (*a*) structural change and information needs, (*b*) production efficiency and technology, (*c*) energy conservation, (*d*) marketing, (*e*) government policies, and (*f*) taxation. Two additional areas, (*g*) off-farm income and (*h*) societal values and goals relating to small farms, were added by the project staff and advisory team after the conference.

Phase II

Phase II began in April 1978. Forty individuals, principally researchers from the academic community and government agencies, were selected to review the existing knowledge and propose a research agenda in each of the eight issue areas. Outlines of the papers were developed at a working conference of authors in June 1978, and a completion date of December 1978 was agreed upon.

On 31 January 1979, 106 individuals representing a wide range of perspectives and backgrounds met at the Nebraska Continuing Education Center on the University of Nebraska campus in Lincoln to review and comment on the papers prepared by the issue groups. In addition to those involved in preparing the papers, participants included representatives of government agencies and public interest groups, as well as selected small farmers who had been delegates to the five regional USDA/CSA/ACTION Small Farms Conferences held during the summer of 1978.

The purpose of the Lincoln Conference was threefold: (*a*) to have the papers reviewed by a diverse group of people actively interested in the area of small-scale farming, to generate comments and suggestions to help the paper writers improve their reviews of the literature; (*b*) to strengthen a research agenda for small farms; and (*c*), as a starting point for Phase III of the Small Farms Project, to begin discus-

[1] A new USDA definition includes a slightly lower (on the average) limit on family income: the median nonmetropolitan family income in the state where the farm is located.

sion of possible policy alternatives that would help improve the incomes of families or individuals living on smaller scale farms. The conference was designed to achieve these goals through a series of small group sessions and plenary sessions.

The papers presented at the Lincoln Conference are being published (with a few exceptions) as a series of eight NRC monographs, listed in the references. Some of the major conclusions and the more salient components of the research agendas suggested in these papers, and in the small working groups at the Lincoln Conference, will be discussed here for purposes of illustration.

Deficiencies in Previous Research

Ideally, research contributes three general kinds of knowledge: (*a*) increased understanding of the existing conditions and trends regarding the survival and well-being of various kinds of small farms in different locations and farming situations; (*b*) better knowledge of the underlying causes of these conditions and trends, the underlying forces, constraints, and opportunities; and (*c*) improved capacity to predict what effects possible alternative actions or inactions may have upon the survival and prospering of various kinds of small farms under various conditions.

The state-of-the-arts papers indicate what past research has contributed to knowledge and what gaps remain to be filled. In general, the gaps are substantial—the ideal listed above has seldom if ever been completely realized. There are some areas (such as taxation and governmental price, income, and credit policies) in which present conditions and trends are well documented, and to some limited extent the underlying causes, constraints, and opportunities are known. But the existing state of the arts is rarely if ever completely adequate to provide a solid basis for predicting the outcomes of alternative policy initiatives under the wide range of conditions and resource combinations found on small farms. There are six general types of deficiencies found in the existing literature.

(*a*) Simplistic definitions: Most studies fail to differentiate among various types of small farms (limited resource, part-time, retirement, commercial, etc.). In most studies, small farms are defined naively by a single dimension, usually a gross sales limitation (such as $20,000), or by the level of one resource used by the farm (acres of land, man-years of labor, number of dairy cows milked, etc.).

(*b*) Obsolescence: Much of the research is out of date, not valid for today's technology, prices, or government programs.

(*c*) Chronic gaps: Other information has never been collected and synthesized; essential studies have never been initiated or completed.

(*d*) Qualitative limitations: Much of the information and research findings are either severely limited in scope (a few counties in one state, for example) or flawed by methodological, empirical, or theoretical deficiencies which preclude any valid generalizations regarding existing conditions, trends, underlying causal factors, or predictions of future outcomes.

(*e*) Fragmentation: Another important deficiency of the entire body of small farms research is its fragmentation. It lacks a comprehensive and explicit causal model[2] linking all of the various conditions and factors that interact to determine (*a*) the essential nature (structure) of agriculture at the firm, community, state, national, and international levels, and (*b*) the policy outcomes with respect to specific goals, such as increased income of small farm families, for example. The typical agenda for small farms research reads like a shopping list written with no specific menu or meal plan in mind—just a string of seemingly unrelated items, with no underlying rationale and no apparent plan or framework for pulling it all together. An illustration of this fragmentation is the contention of many persons that the solution to the problem of low income on small farms is simply to provide better technical information—such as fertilization, improved plant varieties, livestock disease control—while ignoring the harsh realities of the marketplace.

(*f*) Lack of predictive validation: Research to date does not provide a reliable basis for predicting the success or failure of small farms or of various programs intended to help them survive and prosper. This is largely because the economic models (Leibenstein) on which this research is based have never been proven

[2] Such a model is presented in the NRC monograph by Madden, Tischbein, and West, to clarify the importance of this approach and to provide a framework for conceptualizing further research and interpreting research findings.

valid for analyzing or predicting the behavior of small farm families. Conventional neoclassical theory of the firm, which leads to the conclusion that only those firms producing at the low point on a long-run average total-cost curve can ultimately survive, fails to explain both the pluralism (the continued existence of a relatively large number of small farms) and the bifurcation (disappearing middle) of American agriculture.

Brief Suggestions for Further Research

In general, our agenda for small farm research covers a wide range of subjects. The following list is illustrative:

(*a*) Research to predict the impacts on various types of small farms of policy alternatives for price, income, taxation, farm credit programs. (See Spitze et al., and Sisson for more discussion of these points.)

(*b*) Research on marketing, including an examination of how conventional and alternative marketing channels can both hinder and enhance the economic and political prospects of small farms (Thompson).

(*c*) Evaluation of various alternative approaches for providing technical and marketing information to small farms including, but not limited to, the use of paraprofessionals.

(*d*) Determination of both the descriptive and causal aspects of the structure of the small farm sector of American agriculture, including new and better data on the resource endowments, opportunities, constraints, and aspirations of small farms, plus the impacts of farm structural change on rural communities (Tweeten and Huffman, and Rodefeld).

(*e*) Interdisciplinary studies on the processes underlying the nature and scope of agricultural research and Extension, including policy decisions at all levels, systems of professional rewards and incentives, and funding levels for research and Extension relevant to various sizes and types of farms; studies to determine the impact of various kinds of research on the economic and political viability of small farms in various locations and types of farming (Thompson, Buttel et al.).

(*f*) New and better research on economies of farm size. New paradigms, to be developed and tested through extensive research, should avoid the conceptual deficiencies of the earlier studies reviewed by Madden in 1967. Specifically, studies should analyze a wide array of actual and potential farm enterprises, rather than the usual assumption of a rather limited range of crop and livestock enterprises modeled after larger commercial farms. Research should take into account the full array of appropriate technology, including both new and used equipment; custom hiring and cooperative arrangements as well as full ownership of machinery; organic as well as conventional farming practices; and other alternative approaches. Research should recognize that many small farms depend heavily upon off-farm income for their livelihood and as a source of operating and growth capital (Jones, et al.). Off-farm jobs or businesses should be included as enterprises, for example, and the income from all sources should be taken into account in calculating efficiency ratios. This kind of change in the approach to the study of economies of size, viewing the farm as a "goods and services firm" rather than as a producer of a rather limited selection of crop or livestock enterprises (Madden, p. 23) undoubtedly would improve the predictive value of those studies in understanding and predicting trends in the structure of agriculture. Here again the need for actual farm data is imperative, to learn what small farms are actually doing.

These and many other research suggestions are discussed at greater length in the first nine of the forthcoming NCR Small Farms Project Reports and will be integrated in the monograph by Madden, Tischbein, and West.

Conclusion

Clearly, a research agenda in and of itself will not solve any of the problems of small farms, nor will it provide the necessary guidance for public policy. The existence of a comprehensive and well-documented agenda for research on small farms would be useful in (*a*) inspiring individual researchers and research administrators to press ahead in meaningful research areas, and (*b*) providing a framework within which the findings of various individual pieces of research may fit together somewhat more meaningfully. It is also possible that the level of funding allocated to small farm research may be related to the persuasiveness of the research agenda. It is in the hope that these outcomes may occur in the long run that this project has been attempted.

References

Berry, Wendell. *The Unsettling of America: Culture and Agriculture*. San Francisco: Sierra Club Books, 1977.

Buttel, Fred, William Lockeretz, Martin Strange, and Elinor C. Terhune. *Energy and Small Farms: A Review of Existing Literature and Suggestions Concerning Further Research.* NRC Small Farms Project Rep. No. 3, forthcoming 1979.

Emerson, Peter M. "Public Policy and the Changing Structure of American Agriculture." U.S. Congress, Congressional Budget Office, Washington, D.C., Sept. 1978.

Goldschmidt, Walter. *As You Sow*. Montclair, N.J.: Allanheld, Osmun & Co., 1978.

Hoiberg, Eric, and Wallace Huffman. *Profile of Iowa Farms and Farm Families: 1976*. Iowa State University Agr. and Home Econ. Exp. Sta. and Coop. Extens. Serv. Bull. P-141, Apr. 1978.

Jones, Dewitt, Ronald J. Hanson, Sammy Comer, and John Crecink. *Off-farm Earnings and Small Farms.* Washington, D.C.: NRC Small Farms Project Rep. No. 6, forthcoming 1979. Part 1, Dewitt Jones. "Farm and Non-farm Uses of Farm Family Resources: Impact on Farm and Total Farm Family Income." Part 2, Ronald J. Hanson. "Role of Off-farm Income to Small Farm Families." Part 3, John Crecink. "The Rural Labor Market." Part 4, Sammy Comer. "Rural Industrialization and Off-farm Employment Opportunities of Small Farm Families."

Madden, J. Patrick. *Economies of Size in Farming—Theory, Analytical Procedures, and a Review of Selected Studies*. USDA Agr. Econ. Rep. No. 107, Feb. 1967.

Madden, J. Patrick, Delworth B. Gardner, Diana Branch, David Holland, and Howard Osborn. *Production Efficiency and Technology for Small Farms*. Washington, D.C.: NRC Small Farms Project Rep. No. 7, forthcoming 1979. Part 1, J. Patrick Madden. "Agricultural Mechanization and the Family Farm—Some Social and Economic Considerations." Pennsylvania State University AERS Rep. No. 139, Jan. 1979. Part 2, Diana H. Branch. "Tools for Small Scale Farming: An International Picture." Part 3, David Holland. "Production Efficiency and Economies of Size in Agriculture." Part 4, Howard A. Osborn. "Technology and the Small Farm: A Conceptual Framework."

Madden, J. Patrick, Heather Tischbein, and Jerry G. West. *An Agenda for Small Farm Research*. Washington, D.C.: National Rural Center Monograph, Small Farms Pol. Ser. No. 1, forthcoming.

Moles, Jerry. *Societal Values and Goals Related to Small Farms*. Washington, D.C.: NRC Small Farms Project Rep. No. 9, forthcoming.

National Rural Center. *Toward A Small Farms Policy—Phase I*. NRC Small Farms Proj. Rep. No. 1, 17 Nov. 1978.

North Central Regional Center for Rural Development. *Small Farm Research Priorities in the North Central Region*. Ames: Iowa State University, Feb. 1979.

Rodefeld, Richard D., Jan Flora, Donald Voth, Isao Fujimoto, and Jim Converse. *Change in Rural America: Causes, Consequences and Alternatives*. St. Louis: C. V. Mosby Co., 1978.

Schumacher, E. F. *Small is Beautiful, Economics As If People Mattered*. New York: Harper & Row, Publishers, 1973.

Sisson, Charles A. *The U.S. Tax System and the Structure of American Agriculture*. NRC Small Farms Project Rep. No. 4, forthcoming 1979.

Spitze, R. G. F., Daryll E. Ray, Alan S. Walter, and Jerry G. West. *Public Agricultural-Food Policies and Small Farms*. NRC Small Farms Proj. Rep. No. 2, forthcoming 1979.

Thompson, Allen. *Marketing and the Small Farmer*. Washington, D.C.: NRC Small Farms Proj. Rep. No. 5, forthcoming 1979.

Tweeten, Luther, Wallace Huffman, Steven T. Sonka, and Richard Rodefeld. *Structure of Agriculture and Information Needs Regarding Small Farms*. Washington, D.C.: NRC Small Farms Proj. Rep. No. 8, forthcoming 1979. Part 1, Luther Tweeten and Wallace Huffman. "Structural Changes: An Overview." Part 2, Steven T. Sonka. "Consequences of Farm Structural Change." Part 3, Richard D. Rodefeld. "Farm Structural Characteristics: Recent Trends, Causes, Implication and Research Needs—Excerpts."

U.S. Congress, Senate Committee on the Judiciary, Subcommittee on Administrative Practice and Procedure. *Priorities in Agricultural Research of the U.S. Department of Agriculture*. 95th Congress, 2nd Session, Oct. 1977.

U.S. Department of Agriculture, Science and Education Administration—Extension. *National Summary of Regional Small Farms Conferences:* Dec. 1978.

Small Farms Definition and Policy Research Agenda: Discussion

William E. Myers

As befits a beleaguered bureaucrat who has tried to confront small farm issues in one state, I will address some problems likely to arise in translating the findings, recommendations, and implications of the presented papers into tangible programs and policies.

A central theme underlying both papers is the problem of enormous heterogeneity in the small farm sector. So far, public policy has not been adept at dealing with such heterogeneity, and one might reasonably argue that small farm problems persist partially because of this failing. How, then, might we better respond to variety, whether in research or in the formulation of policies and programs?

One begins, I think, with disaggregation. Statistics, such as those Carlin and Crecink present, obscure critical differences between subgroups which, when it comes to delivering services, may be more important than many factors they have in common. The Carlin and Crecink approach will prove more valuable when applied to far smaller areas, certainly no larger than states. Such figures could be expected to vary greatly between these smaller areas, which implies that effective policies and programs may themselves have to vary in important respects. This in turn suggests that nationwide policy instruments may be too blunt to serve as the primary vehicles of small farm assistance. Perhaps the federal government, rather than attempting to take on small farm issues alone, might more effectively use its position to mobilize state, local, and private sector activity in support of small farm needs. It must be recognized that the farming sector is a highly complex system in which a wide variety of actors participate in making critical decisions, and at least certain key actors will have to be involved for small farms to become more successful.

To me this implies, and the California experience would seem to substantiate, that both research and services will have to be established to provide comprehensive focus on small farm problems in defined state or substate regions. In this context, I mildly disagree with Madden's suggestion that more small farm research is needed, in part, to help generalize nationally about how different kinds of farms perform in varying situations. I fear there are too many variables and too many comparability problems for that expectation to be realistic. What we can do right now is focus research and program activities on tangible small farm problems in particular areas, trying to solve them in practical and innovative ways.

Previous attempts at comprehensive programming or coordination—such as state rural development committees—seem to have been too weak, *pro forma,* and government centered to accomplish the job of dealing with small farm problems. We need to work together in ways that are more substantive. At the heart of such cooperation must be a far closer working relationship between state and local government and the universities. For this to occur, some important adjustments will have to be made all around. We bureaucrats will have to force ourselves out of our typical top-down, line-authority mode of thinking so as to open up the decision process to wider participation and better ideas and information, providing researchers with more opportunity to educate us. On the other side, university researchers will need to curb their enviable will-of-the-wisp individualism enough to focus on practical problems, and then to stay with them long enough to produce usable results.

Madden is concerned that the excellent and ambitious research agenda to which he refers will not be implemented, or that it will be implemented badly. He fears a vicious cycle of poor research and inadequate funding. I share his concern, but I would note that, to us bureaucrats, much research seems poor sim-

---

William E. Myers is coordinator of the Small Farm Viability Project for the State of California, Sacramento.

The opinions expressed in this paper are those of the author and do not necessarily represent the position of any department of the State of California.

ply because it is not relevant to real decisions about real issues which real private and public people can act upon. In my view, there is rather more available money that could be turned, at least in part, to small farm research than is commonly recognized in the universities. Much of this money is at sources not conventional to agricultural researchers, and almost always getting hold of it would involve making research pertinent to tangible problems. It may be that the kind of relevant research which could be so funded would not be of interest to academic journals, but then, again, I feel our taxpayer supported universities should exist more to get our problems solved than to promote the fame of individual faculty members.

I would offer a few suggestions for making research outlined by Madden fundable by a variety of agencies having some reason to support assistance to small farms.

(*a*) Researchers should start with a clear view of who is asking what question, in what way, and for what reason. This can be done by searching out and speaking with practitioners faced with the problem. Most of us are aware we have to make too many decisions with too little information, and we would be flattered by your interest. Our problem is that so often researchers do not want to ask a question in the way we are forced by realities to ask it, and hence the findings are of little or no use.

(*b*) Researchers should remember that decision makers probably are working by a decision making paradigm that differs from models most dear to academia. Usually alternatives are weighed by many different kinds of criteria, and researchers who forget this and focus on one set of criteria alone tend to forfeit the context of reality. In many cases, researchers approach a question as though it lies in a single policy domain (e.g., agricultural policy), when in fact it may inhabit several policy domains (e.g., economic development, employment, and social equity).

(*c*) Researchers should make sure they understand legislative and administrative processes pertinent to subjects they research. Many otherwise excellent academics seem to have a poor understanding of government decision-making practices and actors, and consequently miss vast opportunities. Too many researchers have erroneous ideas of the policy process, such as "Legislative branches make policy; executive branches administer it," when, of course, nothing could be further from the truth. Similarly, I have found researchers often too quick to assume that a bureaucracy is a monolith, and that an idea adopted or rejected at the top has no separate life in the ranks. To the contrary, academics could do much to strengthen healthy diversity and debate inside our agencies by seeking out and working with those who are open to their interests.

(*d*) We need much more research about the "next steps" we can take from where we are; optimal solutions are luxuries that policy makers and administrators almost never experience. American democracy moves incrementally. We especially need more studies of successes—of small farmers who succeed and of small farm programs that succeed. We need to be able to estimate the potential that exists for expanding a few successes into many successes. We do not really have to have "predictability," as Madden put it; a significantly better batting average would be help enough for now.

Small Farms Definition and Policy Research Agenda: Discussion

Allen R. Thompson

The paper by Carlin and Crecink lays out quite well the necessity of formulating a definition of a small farm which conforms to the accepted notions as to what constitutes small and which is easily quantifiable for purposes of enumeration and statistical analysis. From the many discussions I have had with various groups, the definition nominally agreed upon by the U.S. Department of Agriculture (USDA) closely resembles that adopted by other groups, such as the National Rural Center, and would appear to meet both criteria—although there could be potential difficulties in identifying what constitutes a significant portion of family income, especially for operations which in a given census year may have experienced a net loss.

Carlin and Crecink also have presented a description of farm families under two alternative definitions: (*a*) small business as defined by gross sales, and (*b*) low income. Their discussion reveals an overlap in the number of farms defined as small under both criteria and a similarity in the characteristics of operators under each of the two definitions.

While I found their paper quite interesting, I did have some problems. In the first place after stating the new USDA definition, they presented no data to indicate the magnitude or characteristics of farm families meeting these criteria. Moreover, while I believe their scheme in figure 1 is helpful in distinguishing the different groups included and excluded by the two definitions, I would have liked to see the characteristics of group A (small by sales, high by income) and group C (small by income, high by sales) shown separately. In this way, the tradeoff between the two alternative definitions would have been more clear. I wonder if that would have revealed the same degree of similarity in characteristics shown in the tables they do present.

Allen R. Thompson is an associate professor of economics, Whittemore School of Business and Economics, University of New Hampshire.

As to the data, I am a bit disturbed by the high potential error associated with the under reporting of farm and perhaps off-farm income. As I understand it, some 12% of the sample failed to report sales of agricultural products which would, I guess, make them small farmers by the gross sales category. In addition, while nearly 80% did report off-farm income, it is impossible in the survey to identify those who failed to report from those with no off-farm income. What this does to the conclusions is unclear.

I would have liked to see the authors stress in stronger language, and perhaps in more detail, the problems inherent in the gross sales concept. They state their difficulty to be the lack of definitive policy objectives inherent in such a definitional concept. More serious to me is the great heterogeneity in what gross sales means in terms of net income for different kinds of farm enterprises. I am glad the USDA definition appears to be moving away from that obsolete and meaningless definition.

A further point not well treated by the paper is the heterogeneity of the group identified as small by any number of definitions. They have given us only a few characteristics, such as age, which show differences within the group. As the authors point out in their paper, the policies for small farmers should be heterogenous because they have different needs and different objectives. So, too, should consideration in a definition be given perhaps to identifying separate and different groups of small farmers. As Madden and Tischbein observe, we need a typology of small farms which distinguishes resource endowments, aspirations, and other characteristics which would enable identification of separate programs and policies to meet the differing needs of this diverse group.

Finally, let me take issue with the characterization of families with income below the median level as limited-resource, or poverty, families. For some of us who propose using a definition of small, such as that proposed by

the USDA, the principal area for farm policy is improved farm income. While no doubt some of those identified as small by this definition lack resources or are poor, others are by most standards moderately successful. While we may wish to target any special small farm programs to a group with less income, I believe many of us wish to separate the concern with poverty, be it rural or farm poverty, from a concern to increase farm incomes of those families seeking that objective.

The paper by Madden and Tischbein presents basically a description and the rationale of the Small Farms Project of the National Rural Center, a project in which I also have been involved. As their paper is almost exclusively about that one project, I wish to comment on what I feel would have made the paper more interesting and insightful although still remaining faithful to their title: "Towards an Agenda for Small Farms Research."

Perhaps one of the major findings in almost every area of the NRC state-of-the-arts review papers was (or in some cases should have been) that small farm research is, for the most part, still to be done. While the authors devoted a paragraph to a listing of the deficiencies, it is perhaps worthwhile to speculate on why the research to date is largely irrelevant or incomplete. In part, it is, as they have stated, a lack of adequate data. Certainly I believe they would agree that the Census of Agriculture is a very poor source of data, especially in the way it is presented. Having to define small exclusively by gross sales as the census requires makes for limited and often meaningless research. Perhaps more important, but unstated by the authors, is the fact that the basic attitudes of USDA and the research community have been such as to preclude the raising of most relevant questions, much less the answering of those questions. Because of the general acceptance of the conclusion that a small farm means inefficiency in production, poverty in terms of income and, for economists, inappropriate allocation of resources, few have worried about the reasons for small farm problems or the contribution of agricultural policy to the declining number of small farms. In the marketing area, for example, the unquestioned acceptance of the efficiency of the current marketing system has led few researchers to explore the relevance or viability of marketing alternatives more suitable to small farms. The latter is, of course, not true for other countries where researchers have helped to develop marketing systems more suitable for small farms.

The assumptions for U.S. researchers have been, and for many remain, that small farms are out of place except for those marginal operators who are stuck because of age, for example, and who are not a farm problem but a welfare problem anyway. If we are to work toward a meaningful small-farms research agenda, we must be willing, as researchers, to take a fresh look at small farm questions and challenge old cliches and old assumptions.

The shortcomings of past research and the necessity for alternative models and alternative assumptions in future research are shortchanged in this paper, although I am sure they are well appreciated by the authors and, I hope, by the research community.

Small Farms Definition and Policy Research Agenda: Discussion

Peter M. Emerson

The paper by Thomas Carlin and John Crecink has two sources of strength: (*a*) their commonsense notion that the definition of a small farm is multidimensional, and (*b*) their use of the 1975 Farm Production Expenditure Survey data. The authors show, for the first time, that low income, small farm families have an important dependence on farming and that they are more closely akin to all low income farm families than to all small farm families.

I believe that the data presented by Carlin and Crecink may stimulate some interesting research projects. For example, why do low income, small farm families that report a negative net farm income appear to be superior off-farm income earners as compared to low income, small farm families reporting a positive net farm income? In short, why are failures on the farm successes off the farm? One possible answer is that families with a negative net farm income need more off-farm income for subsistence. But all of the families under consideration are characterized by low incomes, and it appears reasonable to assume that most of them strive to earn more income. It may be that the success of negative net farm income families in off-farm earnings is more directly related to the fact that they farm fewer acres than the others, or tend to be heavily involved in the production of horticultural crops.

Carlin and Crecink, however, provide very little insight into the importance in absolute terms of the four areas depicted in figure 1. The reader must use a second data source, such as USDA's *Farm Income Statistics*, to estimate farm numbers, share of total farm sales, and other factors that fully describe figure 1. One estimate is that 1.4 million low income, small farm families accounted for about 8% of total farm sales in 1977. The authors also fail to provide information relating specifically to low income, large farm families or to high income, small farm families, although one of their major conclusions is that the current debate about small farms involves important trade-offs between these two groups.

Carlin and Crecink have not directed attention to the fact that some of the most urgent social problems exist among small farmers. How many of the low income, small farm families actually fall below the poverty line? How many are minorities subject to systematic discrimination and often overlooked by existing public programs? It is possible that preoccupation with the structure of agriculture (small farms versus large farms) to the exclusion of other data may direct public attention away from those people most in need of assistance?

In concluding their paper, Carlin and Crecink argue that "the concept [of a small farm] itself does not suggest a clear policy objective." It is my personal opinion that the existing body of research, and the values and goals of most Americans, substantially contradict this argument. I believe that public policies—particularly those relating to price and income support, taxation, credit, research, and extension—ought to be neutral with respect to farm size. Obviously, public policies are not neutral if program benefits are heavily skewed in favor of large farms, if they reduce opportunities to enter farming, or if they tend to discourage the operation of small farm businesses.

My overall assessment of the paper by Madden and Tischbein is that it is rather short on the details of a research agenda and much too long on description of the National Rural Center's Small Farms Project. The reasons for concern about the future of small farms are well presented, though perhaps the authors overstate the potential contribution of small farms to the viability of rural communities. I certainly concur with their recommendation for additional studies of the socioeconomic re-

---

Peter M. Emerson is a principal analyst, Congressional Budget Office, Washington, D.C.

lationships between farming and rural communities. We need to develop research methods that will allow the results of these studies to be generalized and free them from personal bias toward a particular lifestyle.

Madden and Tischbein recognize that the wide diversity of problems and issues makes it difficult, perhaps impossible, to develop a national agenda for small farm research. Given this constraint, I believe it would be useful if the authors simply proposed some guidelines to be followed in developing small-farm research plans. Perhaps the guidelines could take the form of a series of questions to researchers and administrators. For example: Does our research agenda help people fit into the margins of large-scale, industrialized farming? Does our research agenda insure diversity in farming?

I believe that a research agenda explicitly recognizing the option of less specialization will, over a period of time, tend to benefit small farm families without making them dependent on direct government assistance. The range of alternative farming methods and lifestyles to which agricultural research may contribute will be increased greatly if some analysts concentrate on less specialization. One difficulty with this strategy is that the activities of planning and conducting research are controlled by experts who are often willing to consider only the narrow, specialized projects to which their livelihoods are tied.

In addition to the specific research issues suggested by Madden and Tischbein, it seems important to encourage economists and statisticians to get on with the work of establishing linkages between existing data series that describe the characteristics of people and farm businesses. This may enable us to gain much additional information for only a small cost, and with no additional burden on the respondents. Also, I believe that more research based on the direct observation of individual behavior—motives, expectations, and attitudes—would help to improve our understanding of the problems of small-scale farmers and why the farm sector is changing.

Settlement Size, Real Income, and the Rural Turnaround

Irving Hoch

In previous work examining wages and incomes in metropolitan areas (Hoch 1976, 1977), I found that wage rates for the same work increased by about 9% per order of magnitude of population size, and that per capita incomes increased by about 16% with each magnitude of population size. Both the wage and income differentials showed strong persistence over time. I interpreted the wage differential as a compensatory payment, and the income differential as encompassing both the wage differential and differences in factor mix by size of place. The cost-of-living, as measured by a conventional market-basket index, increased by roughly 4.5% per order of magnitude of population, and the remaining wage differential was explained as the net of bads over goods with population size—pollution and congestion costs net of the benefits of increased specialization, such as greater availability of specialized medical services. (Some hedging of these interpretations is necessary. Although considerable effort was devoted to establishing homogeneity in the wage comparisons, some residual heterogeneity of work force may remain. Again, disequilibrium can be a problem in both wage and income comparisons.)

This paper extends the analysis of wage and income differentials to rural occupations and the nonmetropolitan population, thus attempting to bridge the work of some classic studies comparing farm and nonfarm income (e.g., Hathaway) and those relating urban wages and incomes to population size (e.g., Fuchs). In addition, the work is seen as useful in analyzing the rural turnaround, which has received considerable recent attention (e.g., Beale 1975). Results are interpreted as reflecting long-run compensatory payments as modified or distorted by short-run disequilibria.

Irving Hoch is a Fellow with Resources for the Future, Washington, D.C.

The next section analyzes wage rates for two relatively homogenous occupations—hired farm labor and female clerical workers, based on a sample of rural as well as urban counties. The concluding section, recognizing the hazards of income comparisons, considers income and population data for metropolitan areas and nonmetropolitan counties over the period 1969–77. Major conclusions are: (*a*) wage rates increase with population for rural as well as for urban occupations; (*b*) the wage-size relation holds for the small populations of nonmetropolitan counties, as well as for the large populations of metropolitan areas; (*c*) the pattern of nonmetropolitan income differentials then ties neatly into that of metropolitan income differentials; (*d*) the rural turnaround can be interpreted as an equilibrating adjustment, because movement from places of higher to places of lower money wages is consistent with increases in real wages; (*e*) there is little difference in growth in either population or per capita income between nonmetropolitan areas contiguous to and those not contiguous to metropolitan areas, implying that the observed turnaround is not a statistical artifact of urban sprawl extending beyond metropolitan boundaries; and (*f*) the rural turnaround seems best viewed as part of a more general equilibrating process favoring the growth of small relative to large places.

Wage Studies

I asked the basic question: Does the wage-size relation hold for rural occupations and for nonmetropolitan counties? To answer the question, I drew on county data from the 1970 Census of Population and the 1974 Census of Agriculture. Data on median 1969 earnings of female clerical workers and of male hired laborers were obtained from the first source,

while the 1974 value of farm real estate per acre and of estimated annual wages of hired farm workers were obtained from the second source. (The last measure covers farm workers employed 150 days or more.) Although there are some difficulties with these series, they appear to be the best data available at the county level (U.S. Congress).

Four samples were obtained by using all the county observations available for New York, Iowa, Alabama, and California. Those states were selected because of their size, their respective location in one of the four major U.S. regions, and their relatively large number of counties (more than fifty for each). The number of observations varied somewhat between occupations because of incomplete coverage, particularly for farm workers in large metropolitan counties.

The key explanatory variable, area population, was defined as metropolitan area population for counties falling in standard metropolitan statistical areas (SMSAs), and as county population for all other counties, a straightforward extension of the SMSA definition. The spatial unit can be viewed as corresponding to the local labor market or settlement. County and SMSA populations are taken from the 1970 Census of Population and are measured in units of 1,000.

As a first step, real estate value per acre was regressed on spatial-unit population size for each state and for the state data combined in one sample. The log-log form gave the highest explained variance, with positive and statistically significant coefficient in all cases, though some variability occurred between states. Similar results were obtained when the sample was restricted to counties not in SMSAs. Results for the combined state samples were as follows, with log of real estate value the dependent variable:

Sample	Constant	Coefficient of Log Population Size	t-Ratio	$\bar{R}^2$	Number of Observations
All counties	2.223	0.279	12.03	.44	280
Exclude SMSA counties	2.275	0.248	6.31	.51	203

Dummy variables for individual states appeared in the equations as intercept shifters; the constant is the average of individual state intercepts.

Assuming that real estate and land value per acre are well-correlated, a hypothesis explaining the relation of land value and population size is that increases in settlement size cause increases in land values, including farm land values. If more people want to locate in a county, the demand for land and its price, should shift up. Of course, there are alternative hypotheses; a better agricultural base, in terms of better soil, water, topography, climate, or access to markets, can be reflected in farm land values, and in turn, cause greater levels of population. In practice, causation may run in both directions.

Standardized wage rates were related to log of population size, with results in table 1. Standardized wage rates are expressed as a percentage of the average wage rate, and are obtained by dividing each county reading by the average for the specific sample and then multiplying by 100, eliminating differentials between occupations and over time, and facilitating interpretation of results. In the combined samples, dummy variables for state intercept shifters again accounted for state differentials.

The evidence of table 1 supports the hypothesis that wage rates increase with population (a) for rural as well as for urban workers including farm workers, and (b) for nonmetropolitan levels of population (1,000 to 100,000 persons), as well as for metropolitan levels (over 100,000).

The coefficient values in table 1 seem broadly consistent with previous estimates obtained using other data sources for a number of occupations and groups (Hoch 1976, 1977, pp. 38, 39).

Again, when SMSA counties are deleted, the population size effect falls for the hired farm worker, 1969 sample, but it increases for the other two cases, suggesting that the effect is at least as strong in small population locations as in larger places.

Finally, the log of real estate value per acre (RE/A) was brought into each equation as an additional explanatory variable. The general result was that population size dominated land value in the female clerical worker equations, but the reverse relationship held for the farm worker cases. Dominance refers to relative explanatory power of two correlated variables, with the dominant variable having a high t-ratio and relatively large, positive coefficient, and the dominated variable having

Table 1. Regressions of Standardized Wage Rate Estimates on Log of Area Population, by Occupation and Sample

	Female Clerical, 1969				Hired Farm Workers, 1974				Hired Farm Workers, 1969[a]			
Sample	Constant	Coefficient	t-ratio	$\bar{R}^2$	Constant	Coefficient	t-ratio	$\bar{R}^2$	Constant	Coefficient	t-ratio	$\bar{R}^2$
(1) New York	76.7	9.86	6.87	.45	75.0	10.57	3.27	.15	83.9	6.96	1.44	.02
(2) Iowa	75.2	18.82	4.93	.19	87.6	9.39	2.20	.04	80.1	14.69	1.43	.01
(3) Alabama	87.7	7.38	3.52	.15	86.3	8.29	2.03	.05	62.0	22.90	4.28	.21
(4) California	66.8	16.34	7.60	.51	93.6	3.16	1.16	.01	95.0	2.19	0.67	−.01
(5) Four states combined	71.1[b]	13.83	11.93	.59	88.7[b]	7.27	4.33	.28	92.5[b]	9.12	3.18	.46
(6) Four states combined (excluding SMSA counties)	74.6[b]	20.49	5.93	.37	89.0[b]	8.79	1.94	.24	104.1[b]	2.91	0.33	.37

[a] Number of observations for Hired Farm Workers, 1969, by sample, was (1) 53, (2) 84, (3) 66, (4) 45, (5) 248, and (6) 175. Number of observations for other occupational equations was (1) 58, (2) 99, (3) 67, (4) 56, (5) 280, and (6) 203.

[b] Dummy variables for individual states appeared in the equation as intercept shifters; constant shown is average of state intercepts.

a low t-ratio and a small, sometimes negative coefficient. The pattern held in almost all the individual state equations, and here appears clearly in the equation for the combined samples:

Occupation, Sample: Four States Combined	Coefficients Log Pop.	Coefficients Log (RE/A)	t-Ratios Log Pop.	t-Ratios Log (RE/A)
Female clerical, 1969	13.24	2.13	9.23	0.71
Hired farm workers, 1974	1.00	22.50	0.51	5.41
Hired farm workers, 1969	4.36	18.86	1.29	2.60

This result might be interpreted as follows. By way of multiplier effects, land values are likely to be a central ingredient in a conventionally measured cost-of-living index, which includes only market traded goods. As noted earlier, people living in cities (of any size, including small towns) should also be faced with nonmarket costs, including time spent in the journey to work, various forms of pollution, and other disamenities, together hypothesized to outweigh any amenities of urban life. Female clerical workers usually will work in cities, and will be faced with both the market and nonmarket cost items. Further, urban land values may not be highly correlated with farm land values. Consequently, population size will be a better explanatory variable than farm real estate value in explaining clerical wages. But farm workers, by definition, will not be faced with the nonmarket city costs (save for trips into the city), and so will have their wage rates affected only by the "conventional" cost-of-living, better explained by real estate value than by size of settlement.

My basic question, then, is answered affirmatively: the wage-population size relation appears to hold for rural occupations and for nonmetropolitan settlements, as well as for their urban and metropolitan counterparts. Given the importance of wages in income, these relationships should affect our interpretations of rural income and population shifts, including the "rural turnaround." I illustrate this point in detail in the next section.

Income and Population Comparisons

In this section, I change my focus from wages to income. Table 2 compares nonmetropolitan counties to SMSAs grouped by population size, in terms of deflated per capita incomes in 1969 and 1977, growth in per capita income within that period, and growth in population for the same period. The first two columns of table 2 exhibit the general tendency of per capita income to increase with population size. To some extent, this can be attributed to factor mix, in terms of both labor and nonhuman factors of production, but to considerable extent, it should also reflect increasing wage rates for the same work, as documented in the previous section.

As an initial analysis, using data spanning a number of years on metropolitan areas only, the regression of deflated per capita income on the log of SMSA population and a dummy

Table 2. Per Capita Income and Population Growth by Population Size Class, 1969 and 1977

Population Size Categories; (population in thousands as of 1969)	Per Capita Income Deflated by CPI[a] 1969	Per Capita Income Deflated by CPI[a] 1977	1977/1969	Population in Class 1977/1969
	---------- $ ----------			
Non-SMSA Counties	3231.7	3952.4	1.233	1.095
SMSAs by population size				
0–<100	3607.8	4457.4	1.235	1.159
100–<250	3753.4	4466.5	1.190	1.111
250–<1,000	4078.3	4798.4	1.177	1.092
1,000–<2,500	4569.9	5276.5	1.155	1.088
2,500–<9,000	5146.5	5839.5	1.135	1.018
9,000 + (NYC)[b]	5392.7	5593.5	1.037	0.946

Source: Developed from data tape from U.S. Bureau of Economic Analysis. Some of the data is listed in *Survey of Current Business*, April 1979.

[a] CPI is consumer price index, 1972 = 100.

[b] NYC is New York City metropolitan area.

variable for the South yielded a statistically significant coefficient for the population measure in every year examined. Over the period 1950–72, this coefficient was relatively stable, and it implied that per capita incomes increased by about 16% per order of magnitude of population (Hoch 1977, p. 44). Since 1972 there has been a mild downtrend in the coefficient, so that by 1977, per capita incomes increase by only 13% per order of magnitude of population (from newly run individual regressions 1973–77). An appealing hypothesis explaining the downtrend is a temporary disequilibrium in favor of smaller places, i.e., people in smaller places currently are receiving more than is needed to keep everyone in their place, so there is net migration from larger to smaller places. In table 2, note the inverse relationship between population size (as of 1969) and growth—both growth in per capita income and growth in population.

The average 1969 population of the non-SMSA county was 21,050 (U.S. BEA). An SMSA one population magnitude larger falls in the second SMSA size grouping in table 2 (100,000 to 250,000), and the per capita income for that class exceeded the corresponding non-SMSA value by exactly 16% in 1969 and 13% in 1977. Those specific results are fortuitous embellishments to the interpretation that the non-SMSA income pattern fits the income-population pattern observed for larger places, again paralleling a conclusion of the previous section.

Table 3 presents population and income comparisons over the period 1969–77. The start of the "rural turnaround" might well be dated as 1971, because nonmetropolitan population as a percentage of the U.S. total turns up in that year, and the percentage increases thereafter. In contrast, non-SMSA per capita income increased relative to SMSA levels to 1973, but then fell somewhat through 1976, with no appreciable change in 1977. Net income per farm peaked at a very high level in 1973 (USDA, p. 15), probably a major factor explaining the observed pattern. But despite the turn-down from the 1973 extreme, the 1977 relative income value is well above the 1970 value. If we entertain the hypothesis that the equilibrium percentage is closer to the 1970 than the 1977 figure, given the direction of recent net migration (e.g., U.S. Census 1978, P-20), we can expect a continuation of the rural turnaround for some time to come. Under this interpretation, of course, we can explain the apparent anomaly of people migrating from higher to lower wage localities (Zelinsky), since real incomes obtained in the new locations are higher than in the old.

The rural turnaround is sometimes hypothesized to be a statistical artifact reflecting urban sprawl which has occurred beyond officially designated SMSA boundaries. Several authors (Beale 1977; McCarthy and Morrison) have developed population data which counters this interpretation, showing net growth in rural areas at some remove from SMSAs, as well as growth occurring nearby. Let me extend that discussion by drawing on some additional evidence, which also bears on my interest in the income-population size relation. That evidence was developed using a sample of 711 non-SMSA counties, out of the U.S. total of

Table 3. U.S. Metropolitan versus Nonmetropolitan Population and Income Comparisons, 1969–77

Year	Population in Non-SMSA Counties as Percentage of U.S. Population	Per Capita Income, Non-SMSA Counties as Percentage of SMSA Counties	Per Capita Income as Fraction of Previous Year Per Capita Income: SMSA Counties	Per Capita Income as Fraction of Previous Year Per Capita Income: Non-SMSA Counties
1969	26.04	71.45	1.001	1.014
1970	25.91	72.61	0.999	1.015
1971	25.97	73.20	1.016	1.024
1972	26.10	74.41	1.049	1.067
1973	26.17	78.64	1.032	1.090
1974	26.21	77.37	0.985	0.969
1975	26.35	77.33	0.990	0.989
1976	26.44	76.34	1.035	1.022
1977	26.53	76.42	1.032	1.033

Source: Data tape cited in table 2 and *Survey of Current Business* 1973, 25, for calculation of 1969 growth rates.

2,467 such counties; 342 of the sampled counties were contiguous to metropolitan areas, i.e., bordered on an SMSA county, and 369 were noncontiguous. I developed those subsamples using maps appearing in the Census *Current Population Reports* (Series P-26), with each subsample covering most states and selected so that counties were widely and relatively evenly distributed over each state.

Table 4 compares deflated per capita incomes for selected years over the 1969–77 period for the contiguous versus noncontiguous groupings, with each grouping subclassified into population size classes.

Table 4 can support two major conclusions. The first is that the general pattern of increased per capita income with population size occurs for the four largest size classes, but generally the smallest size class (below 10,000 population) exhibits an income level above the next size class and roughly equal to that of the middle grouping (25,000 to 50,000). This suggests a U-shaped pattern of compensatory payments. It is an appealing hypothesis that minimum disamenities occur in the 10,000 to 25,000 range, making that population level "optimal" in terms of preferences; below that point, relative isolation and small size may impose net costs, causing increased wages and incomes as an equilibrating adjustment. But this hypothesis needs some intensive testing.

The second major conclusion suggested by table 4 is the occurrence of basically similar patterns for contiguous and noncontiguous counties. Such occur both for deflated per capita incomes and for changes in per capita incomes and population. Regressions were run relating per capita income for the sampled non-SMSA counties to log of population, regional dummy variables, and a dummy variable expressing SMSA proximity (contiguous counties were assigned a value of one, and noncontiguous counties a value of zero). The coefficient for SMSA proximity was positive and often significant, but its effect was relatively minor, indicating that contiguous counties' per capita income is around 2% above that of noncontiguous counties. This might be either a factor mix or a compensatory payment effect. As indicated above, the U-shaped pattern for deflated wages suggests the need for experimentation with other than logarithmic equation forms, but the SMSA proximity effect can be expected to persist at around the reported magnitude. It is of some consequence for the general argument of this paper that the coefficient for log of population was generally positive and significant, though the 1973 value was negative and significant, no doubt the effect of the temporary increase in agricultural income.

Statistical tests also indicate that only minor differences occur in growth in population and income between the two sets of counties. Segregating the data by region, proximity to SMSA was not significant in explaining change

Table 4. Comparisons of Per Capita Incomes and Growth in Income and Population for a Sample of Nonmetropolitan Counties Classified by Population Size and Location

1969 Population (in thousands)	Number of Observations	Per Capita Income Deflated by CPI, Selected Years						Changes: 1977/1969	
		1969	1971	1973	1975	1976	1977	In Per Capita Income	In Population
		$							
		Noncontiguous Counties							
0–<10	118	3126.9	3283.9	4402.6	3787.9	3644.1	3792.1	1.213	1.112
10–<25	139	2916.1	3065.7	3676.1	3447.9	3492.5	3606.0	1.237	1.109
25–<50	71	3134.6	3275.5	3726.8	3604.7	3723.5	3874.6	1.236	1.087
50–<75	38	3469.7	3594.3	4032.0	3973.0	4130.2	4249.6	1.225	1.116
75–<100	3	3726.0	3762.4	4153.5	4133.6	4169.2	4361.6	1.171	1.095
All	369	3089.1	3235.9	3958.7	3646.5	3656.6	3789.6	1.227	1.104
		Contiguous Counties							
0–<10	69	3107.1	3259.8	4280.8	3719.7	3582.7	3589.6	1.155	1.115
10–<25	117	3030.3	3171.5	3900.8	3630.4	3637.1	3792.1	1.251	1.098
25–<50	89	3215.3	3339.0	3825.5	3724.8	3826.4	3965.7	1.233	1.125
50–<75	52	3549.8	3652.7	4047.8	3942.4	4072.5	4170.3	1.175	1.119
75–<100	15	3683.9	3785.0	4161.1	4055.3	4176.4	4276.3	1.161	1.089
All	342	3201.6	3333.0	3991.7	3739.1	3765.2	3875.2	1.210	1.124

in income in either the North or South; it was significant in explaining population change in the South, but not in the North. The Southern result involved 9% growth for noncontiguous counties and 12% growth for contiguous counties. Hence, proximity to a metropolitan area does not seem to be a major factor explaining the rural turnaround.

Speculations on underlying causes of the rural turnaround point to such factors as improvements in transportation and communication; the impact of higher energy prices on both the supply and demand side; and the effects of increased sensitivity to the environment, and of environmental regulation. In addition, inflation in tandem with the progressive income tax tends to increase real taxes because people are moved into higher tax brackets even if real wages are unchanged. The effect appears to be stronger the higher the initial money income level, based on a detailed examination of tax rates and taxes under inflation. Consequently, people will tend to shift to places offering lower money wages but equal real wages, relative to alternative locations, since this will increase real disposable income. (Our income comparisons by location would be improved if we developed data on disposable income per capita.) A specific implication is that people will tend to move from larger to smaller places; given current rates of inflation, such shifts should become even more pronounced over the next several years.

Finally, the shifts involved in the rural turnaround, whatever their causes, seem part of a more general process occurring over the full range of settlement sizes. In turn, this suggests that we may improve our analysis by perceiving rural and urban as part of a continuous, integrated system, rather than as a sharp dichotomy.

References

Beale, Calvin L. "The Recent Shift of United States Population to Non-Metropolitan Areas, 1970–75." *Int. Reg. Sci. Rev.* 2(1977):113–22.

———. *The Revival of Population Growth in Non-Metropolitan America.* USDA ERS-605, 1975.

Fuchs, Victor R. *Differentials in Hourly Earnings by Region and City Size, 1959.* National Bureau of Economic Research Occas. Pap. 101. New York, 1967.

Hathaway, Dale E. *Government and Agriculture,* pp. 32–43. New York: Macmillan Co., 1963.

Hoch, Irving. "City Size Effects, Trends and Policies." *Science* 193(1976):856–63.

———. "Variations in the Quality of Urban Life among Cities and Regions." *Public Economics and the Quality of Life,* ed. Lowdon Wingo and Alan Evans, pp. 28–65. Baltimore, Md.: Johns Hopkins University Press for Resources for the Future, 1977.

McCarthy, Kevin F., and Peter A. Morrison. "The Changing Demographic and Economic Structure of Nonmetropolitan Areas in the United States." *Int. Reg. Sci. Rev.* 2(1977):123–42.

U.S. Department of Agriculture. *State Farm Statistics.* ESCS Statist. Bull. 609, Sept. 1978.

U.S. Department of Commerce, Bureau of the Census. *Current Population Reports, Geographical Mobility: March 1975 to March 1978,* series P-20, no. 331. Washington, D.C., Nov. 1978.

———. *Current Population Reports, Population Estimates,* series P-26, individual state reports. Washington, D.C., 1978.

———. *General Social and Economic Characteristics, Final Report PC(1)-C, Census of Population: 1970,* individual state, table 122, "Occupation and Earnings for Counties: 1970." Washington, D.C., 1972.

———. *Vol. 1, State and County Data, 1974 Census of Agriculture,* individual state, chap. 4, county data. Washington, D.C., 1977.

U.S. Department of Commerce, Bureau of Economic Analysis. "Residence Adjusted Total Personal Income, Per Capita Personal Income, and Population: U.S., States, SMSA's and Counties." Computer data tape for 1969 through 1977.

U.S. Congress, Joint Economic Committee. *Public Hearings before the National Commission on Employment and Unemployment Statistics,* vol. 3, pp. 136–49. Prepared for the Joint Economic Committee, 95th Congress, 2nd Sess., 20 Dec. 1978. Washington. 1979.

Zelinsky, Wilbur. "Coping with the Migration Turnaround: The Theoretical Challenge." *Int. Reg. Sci. Rev.* 2(1977):175–78.

Residential Preferences, Quality of Life, and the Population Turnaround

Don A. Dillman

In the early 1970s, before we had statistical evidence of renewed population growth in rural America, several residential preference surveys were taken. The results showed rather dramatically that if people were free to choose they would prefer to live in rural places rather than in cities. Particularly evident was an aversion to living in very large cities (Mazie and Rawlings, Zuiches and Fuguitt 1972, Dillman and Dobash).

Results of these surveys were viewed by some people as a novelty; interesting but not very useful, especially if one's interest were in predicting migration between rural and urban places. Preferences for living in a particular geographic location, other things equal, have never been a very good predictor of rural-urban migration movements. The simple reason is that these other things were not equal. During the first two-thirds of this century millions of rural people found it necessary to choose between an attractive social and natural environment on the one hand and economic well-being on the other. For the most part, they chose the latter and migrated to cities.

Until recently, discussions of whether people's residential preferences affected their geographic mobility were often cut short with such cryptic comments as "rural people have voted with their feet instead of their hearts," leaving the impression that people's residential aspirations were irrelevant to their actual behavior. Even those involved in the early preference surveys tended to justify them as efforts to find out whether the desire to live in more rural environments was sufficiently strong to warrant a deliberate governmental effort to redistribute the population of the United States (cf. Commission on Population Growth and the American Future, 1972 and Dillman and Dobash 1972).

The discovery in the mid-1970s that virtually all rural regions of the country (although certainly not all individual counties or towns) were showing modest growth made arguments for a redistribution policy obsolete almost before they were published. More importantly, it encouraged a reexamination of the possible relevance, if any, of residential preferences in explaining the renewed growth of rural America. My purpose in this paper is to discuss the possible role of preferences, or, to state it in a more general way, the search for a better quality of life, as a determinant of movement from cities to rural places.

The Population Turnaround and Possible Reasons for It

An examination of the role that residential preferences may have played in the population turnaround cannot be done without first considering what is known about the extent of renewed population growth in rural America and various explanations for its occurrence.

First, between 1960 and 1970 the Standard Metropolitan Statistical Areas (hereafter referred to as "metro" areas) of the United States grew at the rate of 1.6% per year compared to .4% for nonmetro counties. But between 1970 and 1975 the relative growth rates reversed with metro areas slowing down to only .8% per year compared to 1.2% per year for nonmetro locations (Beale 1977). Secondly, although some growth in nonmetro counties is the result of "spillover" from metropolitan counties to those that are adjacent, much of it is not, because the nonmetro coun-

---

Don A. Dillman is a professor in the Department of Sociology and Chairperson in the Department of Rural Sociology, Washington State University.

Scientific Paper No. 5402, College of Agriculture Research Center, Project 0377.

Helpful comments from Edwin Carpenter, William Freudenburg, Barbara Hawkins, John Wardwell, and James Zuiches are gratefully acknowledged by the author.

ties that are not adjacent to metro areas have also been growing at a rate faster than the metro centers. Thirdly, the turnaround is spread throughout the United States. By 1975 the nonmetro counties which were not adjacent to metro counties located in only three of the 26 economic subregions of the United States continued to exhibit net outmigration. Based upon these and other findings, McCarthy and Morrison have concluded that "metropolitan expansion is being supplemented by self-contained local urbanization even in remote regions of non-metro America" (p. 18).

We cannot be sure at this time how long lasting the turnaround is likely to be, but it appears to be continuing into the most recent period for which data are available, i.e., 1975–78. Although some of the nonmetropolitan growth coincided with the economic recession of the early 1970s, it is continuing in these better economic times. The migrants to metro counties continue to be outnumbered by those who are migrants moving to nonmetro counties by a ratio of 5 to 4, or a total of 1.1 million people from 1975 to 1978 (U.S. Census 1978).

Many factors may be contributing to the post-1970 growth of nonmetro counties. Among the explanations for which some evidence has been provided are these (DeJong and Sell; Beale, 1975, 1977; Wardwell; McCarthy and Morrison; Morrison; Carpenter, 1977; and Blackwood and Carpenter, 1978); (*a*) continued growth of metropolitan centers and their expansion (spillover) into adjacent nonmetro counties; (*b*) decentralization of manufacturing in pursuit of lower land and wage costs; (*c*) increased employment in service occupations; (*d*) early retirement coupled with higher retirement incomes; (*e*) increased per capita disposable real income; (*f*) increased pursuit of leisure activities and the resultant development of retirement centers outside of Development of retirement centers outside of the sunbelt areas of the United States; (*h*) increased enrollments in nonmetro colleges and universities; (*i*) growth of state governments; (*j*) leveling off of loss of farm population; (*k*) youth revolution with anti-materialistic movement, anti-urbanism and an increase in alternative lifestyle agriculturists; (*l*) narrowing of traditional gaps in urban and rural lifestyles; (*m*) more long distance commuting) (*n*) energy and mineral exploitation; (*o*) completion of interstate highway system; (*p*) lower cost of living in rural areas; (*q*) increased fear of crime and concern with urban disamenities (crime, congestion, and pollution).

The factors mentioned above are diverse. They exhibit varying levels of specificity and lack mutual exclusivity. Many appear to be interrelated. It is beyond the scope of this brief paper to further categorize and attempt to sort out the extent to which each of these factors is contributing to the population turnaround. However, this list suggests that a multitude of factors are contributing; a singular explanation of the turnaround does not seem possible.

We are analyzing a very recent phenomenon. The first systematic evidence of the turnaround was published only four years ago (Beale 1975) and, despite the widespread nature of the phenomenon, insufficient time has elapsed for the normal accumulation of a data base that would allow the detailed analysis necessary for determining the relative importance of these possible contributors to the turnaround.

Several (though certainly not all) of the possible causes of the population turnaround that are listed above suggest a preference for living in more rural settings. For example, early retirement coupled with higher retirement incomes frees people to pursue residential preferences. Such people could perhaps just as easily move to (or remain in) cities if that were their preference. The narrowing of differences in rural/urban lifestyles (from indoor plumbing and electricity to color T.V. reception and senior citizen centers) suggests that it is no longer necessary to give up many of the amenities in a rural residential location, thus increasing the attractiveness of rural living. Growth from recreational development suggests the inherent attractiveness of rural places. More long-distance commuting suggests a willingness of some people to incur the costs of that commuting in order to have a particular residential location. It is even possible that some of the decentralization of manufacturing and expanded employment in service occupations is the result of jobs following people rather than the reverse, as traditionally would have been expected.

My discussion to this point certainly does not prove that preferences for rural living are causing or even contributing to the population turnaround. However, I believe there is sufficient indication of their playing a role in the turnaround to warrant a detailed investiga-

tion of the nature of that role, and the reasons people hold rural residential preferences.

Residential Preferences of the American People

All of the residential preference surveys done since 1970 indicate that in general the American people prefer residential locations more rural than their present ones (Ryan, et al.; Carpenter, 1975; Zuiches and Fuguitt, 1972; Fuguitt and Zuiches; Mazie and Rawlings; Dillman and Dobash; Dillman; DeJong and Sell). For example, a 1974 national survey, one of the most comprehensive surveys that has been done, found that whereas 40% of the population lived in cities of more than 50,000 only 21% preferred to live there (Zuiches and Fuguitt, 1976).

At the same time these surveys have revealed a desire not to escape entirely from urban areas. This same national survey showed that the percentage of people who would opt for living more than 30 miles away from a city of 50,000 or greater is only slightly more than now lives there, 21% actual versus 26% preferred. Taken at face value, preference surveys suggest that if people were to follow their preferences most of the growth would be in the general vicinity of small and medium cities and come at the expense of the very large cities.

The anti-large city attitudes of people also are revealed in other ways. When asked where they would least like to live more than 80% of the respondents in a statewide survey of Washington State residents identified large metro areas containing a city of more than 500,000 whereas only 16% responded that they would least like to live in a rural region with no place as large as 2,500 (Dillman and Dobash).

The greater attractiveness of rural places also is documented by an intriguing question from a 1972 national survey reported by Fuguitt and Zuiches. Respondents were categorized according to whether they most preferred to live in (*a*) metro size cities (50,000 or more people), (*b*) the metro-ring around them (within 30 miles), or (*c*) further away. The percentage choosing each category as first choice was 19%, 55%, and 26%, respectively. But, when those who gave the metro-ring areas as their first choice were forced to choose between the remaining two options, four out of five opted for the more rural choice instead of the larger cities (Fuguitt and Zuiches). However, the preference for rural living is not unconditional. When potential negative consequences of a move to rural areas were presented to people holding rural preferences in the national survey their interest dropped markedly. The authors report that about half would give up the rural preference in the face of a lower income and other potential negative consequences (Zuiches and Fuguitt, 1976). In a survey of Arizona residents it was found that the proportion of respondents interested in nonmetro living dropped from 52% to only 14% under the stringent conditions of a 10% loss of income and a commute of at least an hour to work in a major city (Carpenter, 1977).

Finally, some research evidence suggests that the preference for a more rural environment is intertwined with the desire to live in the countryside. In the previously mentioned Washington State survey 65% indicated they would prefer living outside rather than inside the city limits of the nearest community (Dillman and Dobash). The proportion stating this preference increased steadily as city size preference decreased. Forty-five percent of those who opted for a community size of 500,000 wanted to live outside the city limits as did 83% of those who opted for a community size of less than 2,500 people. To many people a rural preference may imply a home in the country complete with trees, spacious yard, and other idyllic qualities.

Have Preferences Changed?

To the extent that preferences are influencing the population turnaround, it may, on the one hand, be a case of long-standing preferences being realized. On the other hand, it may be the result of a recent increase in rural preferences. There is very little evidence available with which to answer this question, but the data suggest that a change in preferences may have occurred. The 20 cross-sectional surveys that have asked a preference question date only from 1966, except for an isolated 1948 effort (Dillman). The wide variety of question wordings make it impossible to infer a change in preferences with one exception. Five Gallup surveys conducted from 1966 to 1976 show a steady decrease in the percentage opting for the somewhat vague category "city" from 22% in 1966 to only 13% in 1976.

Other evidence of a possible increase in preferences for rural living comes from a longitudinal survey of rural youth from Michigan's Upper Peninsula (Zuiches and Rieger). In this unique study high school seniors were surveyed in 1957, 1968, and 1974. The 1957 graduates were resurveyed in 1968 and again in 1974; the 1968 graduates were also resurveyed in 1974. It is possible from this series of surveys to determine whether residential preferences are different among the classes at the time each graduated and whether preferences changed in later years. The authors report that preferences for rural and open country living were greater for the later graduates at the time of their graduation, being 11% for 1957 females compared to 19% for 1974 females; and 21% for 1957 males compared to 34% for 1974 males. Also, preferences for rural and open country increased with each successive interview of the 1957 seniors so that in 1975 44% of the males (versus 21% in 1957) and 37% of the females (versus 11% in 1957) stated this preference. A similar change occurred among the 1968 graduates. These Michigan data are consistent with results from a series of surveys from 1966 to 1977 of high school students in Texas, Georgia, and South Carolina. In this six-year period there was a definite shift in preferences toward living in rural areas among both blacks and whites (Cosby and Howard).

Are Migrants Following Their Preferences?

The Michigan study also examined the correspondence between original preferences and locations of respondents when they were reinterviewed. The authors report increased congruence. Fifty-nine percent of the 1957 seniors were living in their originally preferred location seven years later. By 1975, 68% were living in accordance with their preferences. Other results in this study show that among those who originally preferred an urban location and achieved it, nearly half changed to holding a rural preference. In sharp contrast, however, fewer than 8% of those who originally preferred a rural location and achieved it changed to holding an urban preference.

The authors conclude that the increase in rural population growth, at least in northern Michigan, is partly attributable to greater rural preferences among rural youth and that part of the increased immigration to rural areas may be the result of changes in preferences of people who previously migrated from rural to urban areas.

The only longitudinal study of a more general population which has measured original preference and subsequent migration is DeJong and Sell's survey of 1,096 Pennsylvania households in 1974 with the follow-up interview a year later. Since only 14% of all movers achieved their residential preference by moving the authors concluded that preferences had little relationship to actual population dispersal behavior. However, their analysis had two major limitations. One was the very short time period between the original survey and the follow-up. The other limitation was the inclusion of local intra-community moves in the analysis. Since the reasons for local mobility (a major factor being housing size and quality) often differ from those leading to inter-community migration, Fredrickson et al., have reanalyzed DeJong and Sell's data, excluding local moves. They found that 79% of the inter-community movers had gone in the direction of their preferences. Neither the Michigan nor Pennsylvania surveys are without limitations, but both suggest that people are acting on their preferences.

Searching for an Improved Quality of Life

Presumably, people who state a rural preference are seeking to improve their quality of life in some way. Several studies have attempted to ascertain the community attributes that are being sought. Data reported by Fuguitt and Zuiches suggest that people who state a rural preference may hold a higher priority for certain community attributes than those who state an urban preference. When asked to indicate whether each of ten community attributes were a reason for their preference, those with rural preferences were substantially more likely to mention these reasons: less crime; quality of air and water; better for children; and lower cost of living. Respondents holding urban preferences were substantially more likely to give these reasons for their choice: better jobs, higher wages, and contacts with a variety of people. The remaining reasons were mentioned only slightly more often by respondents holding rural preferences: recreation or culture, near family or friends, and better schools.

In a 1971 Washington State survey respondents were asked to indicate whether they felt

Table 1. Residential Preferences of Metro (SMSA) Residents versus Percentage that Believe Life is Best in Metro Places for Selected Quality of Life Indicators

	Believe Life is Best in Metro Places	
Quality of Life Items	Prefer to Stay Metro Residence (% of 783)	Prefer Move to Nonmetro Residence (% of 454)
1. Availability of jobs	94.8	79.9
2. Recreation/entertainment opportunities	86.4	53.0
3. Adequacy of medical care	87.1	58.1
4. Lowest costs for food and services	74.0	49.2
5. Equality of opportunity for all residents	69.4	47.4
6. Lowest costs for public services	62.6	38.5
7. Adequacy of public education	71.2	31.3
8. Adequacy of police protection	61.6	27.5
9. Protection of freedom and privacy	51.5	13.6
10. Quality of religious life	34.7	14.1
11. General satisfaction of residents	37.0	7.4
12. Place in which to raise children	40.3	5.3
13. General mental health of residents	29.7	9.7
14. Respect for law and order	20.9	8.4
15. Amount of voice residents have in deciding community affairs	18.0	7.4
16. Community spirit and pride	18.3	4.4
17. Friendliness of people to one another	13.2	3.9
18. Absence of illegal drug use	9.8	5.7

Source: Adapted from Dillman and Dobash, p. 23.

the quality of life for eighteen attributes would be better in metro or nonmetro communities (Dillman and Dobash).

First, those who prefer rural areas were less likely on every item to perceive that life was best in metro communities. Secondly, the availability of good jobs stands out as the one item on which there was very strong consensus that the quality of life was better in metro areas. Further, a majority of those with rural preferences felt that metro areas were best on only three items compared to nine items for those expressing an urban preference. There were eleven items on which a majority of both categories of respondents indicated that life was best in nonmetro areas, but it can be seen that all of these items reflect the more intangible qualities of community life, e.g., respect for law and order and friendliness of people to one another.

Carpenter (1975) has presented further insight into how the desire for certain community attributes may relate to preferences for rural living. He reports that Arizona residents who preferred metro size communities were significantly more likely to deem a wide variety of stores and businesses, cultural opportunities, and opportunities for eating out as "essential" in the community where they choose to live. Those who preferred nonmetro living were significantly more likely to deem low levels of pollution, more privacy, and more outdoor recreational opportunities as essential.

Together, the data from these surveys suggest that those who prefer rural living may be looking for different attributes in their communities. They are also more likely to believe these attributes are in abundant supply in rural communities.

These respondents' views of rural places and their chances of finding satisfaction may be realistic, judging from quality of life surveys of current rural residents. National surveys have shown that residents of smaller communities are less satisfied with many community services than the residents of all but the largest cities. However, on the whole, rural residents are much more satisfied with their communities. Elsewhere I have suggested as a reason for this phenomenon that rural people weight the less tangible community qualities (e.g., items such as 9–18 in table 1) more heavily than the quality of specific services when evaluating their communities (Dillman and Tremblay).

Whether such quality of life motivations outweigh job considerations in migration deci-

sions has been examined by Williams and Sofranko. Their sample survey of 708 people who had migrated sometime since 1970 to one of the 75 high immigration (greater than 10% since 1970) nonmetro counties in ten North Central Region states led them to this conclusion:

> . . . The findings are consistent with the argument that migration from metropolitan to nonmetropolitan areas is, as reported by migrants, substantially a function of the unattractiveness of urban areas and the relative attractiveness of more rural areas, and that it is based more on environmental factors than on employment. (p. 247)

Williams and Sofranko base their conclusion on results of a meticulous coding and analysis of responses to questions about reasons respondents gave for leaving their previous metro residence and selecting their nonmetro location. Employment related reasons were offered by only 24% of the respondents. Other reasons mentioned included ties to area of destination (7%), environmental "push" factors (26%), environmental "pull" factors (14%), retirement (17%), and other reasons (11%). In sharp contrast, 46% of the people who moved from other nonmetro locations to these counties offered employment-related reasons for their move. This figure is much closer to data from a national housing survey that showed 47% of the people who moved throughout the United States between 1974 and 1976 gave job related reasons (Long and Hansen, 1978).

Williams and Sofranko also report that those who move for environmental reasons were no more likely to experience a drop in income than those who moved for employment-related reasons; however, nearly twice as many (42% versus 22%) of those that moved for job reasons were earning more money at the time of the survey. The authors' overall conclusion is that migrants tend to view their behavior in terms of the relative merits of rural versus urban living, and they conclude:

> These migrants, then, are different from those in national surveys not so much as a function of moving for environmental-amenity type reasons to the exclusion of employment considerations, but rather as a function of the fact that quality of life kinds of considerations seem to rank higher in their perceived causal structure. (p. 254)

Conclusion

To conclude, from the available evidence, that residential preferences for a rural location are a cause of the population turnaround would be seen by many as tantamount to declaring "guilt by association." The population turnaround is a very recent phenomenon, and not enough time has passed for the needed longitudinal research to have been conducted. Further, the research designs needed to confirm or deny the importance of preferences are neither simple nor inexpensive to implement. However, the evidence suggesting that residential preferences are influencing migration decisions is such that it is far less tenable to assert that residential preferences have nothing to do with the turnaround. To do so would require us to ignore all past research on preferences.

The available evidence clearly shows that Americans prefer, other things equal, to live in more rural locations than where they presently live. The imposition of severe income and commuting constraints diminishes, but by no means eliminates, interest in rural living. Other research indicates rural preferences have been increasing during the past decade and that some Americans have been able to follow their preferences. Still other research shows that people who want to live in rural places are looking for community features that are likely to be found there; and, recent migrants from metro to nonmetro counties are more likely to state environmental reasons than job-related reasons for having moved to their new location. But the strongest evidence that residential preferences are contributing to the turnaround, is not the results of any one study; instead it is the striking consistency among the results from all studies.

Because I am not an economist I cannot suggest how residential preference concepts can be incorporated into economic models for explaining migration. However, I would urge that ways be found to do that, just as I urge my own colleagues who have produced much of the residential preference literature to find ways of incorporating economic influences into their own migration models. The turnaround seems to be a product of a number of factors which act with and through one another, only one of which is preferences. It would seem that whether we succeed in understanding the causal structure of the re-

surgence of growth in rural America will depend upon how well we are able to influence one another's research.

References

Beale, Calvin L. "The Recent Shift of United States Population to Non-metropolitan Area, 1970–75." *Int. Reg. Sci. Rev.* 2(1977):113–22.

———. *The Revival of Population Growth in Nonmetropolitan America.* USDA ERS 605, 1975.

Blackwood, Larry G., and Edwin H. Carpenter. "The Importance of Anti-Urbanism in Determining Residential Preferences and Migration Patterns." *Rur. Soc.* 43(1978):31–47.

Carpenter, Edwin H. *Residential Preference and Community Size: Implications for Population Redistribution in Arizona.* Dep. Agr. Econ. Rep. 7, University of Arizona, 1975.

———. "The Potential for Population Dispersal: A Closer Look at Residential Preferences." *Rur. Soc.* 42 (1977):352–370.

Commission on Population Growth and the American Future. *Population and the American Future.* Washington, D.C., 1972.

Cosby, Arthur G., and William G. Howard. *Residential Preferences in America: The Growing Desire for Rural Life.* USDA Ext. Serv. Rur. Dev. Series, 1976.

De Jong, Gordon F., and Ralph R. Sell. "Population Redistribution, Migration, and Residential Preference." *Annals, AAPSS* 429(1977):130–44.

Dillman, Don A. "Population Distribution Policy and People's Attitudes: Current Knowledge and Needed Research." Paper prepared for the Urban Land Institute under a grant from HUD, 1973.

Dillman, Don A., and Russell P. Dobash. *Preferences for Community Living and Their Implications for Population Redistribution.* Washington State University Agr. Exp. Sta. Res. Bull. 764, November, 1972.

Dillman, Don A., and Kenneth R. Tremblay, Jr. "The Quality of Life in Rural America." *Annals, AAPSS* 429(1977):15–129.

Fredrickson, Carl, Tim Heaton, Glenn Fuguitt and James Zuiches. "Residential Preferences in a Model of Migration Intentions." Unpublished manuscript, 1979.

Fuguitt, Glenn V., and James J. Zuiches. "Residential Preferences and Population Distribution." *Dem.* 12 (1975):491–504.

Long, Larry H., and Kristen A. Hansen. "Reasons for Interstate Migration: Jobs, Retirement, Climate and Other Influences." Paper presented to Southern Regional Demographic Group, San Antonio, Texas, 11–13 October 1978.

Mazie, Sara Mills, and Steve Rawlings. "Public Attitude Towards Population Distribution Issues." *Population, Distribution, and Policy, Part V.* Washington, D.C.: The Commission on Population Growth and the American Future, 1972.

McCarthy, Kevin F., and Peter A. Morrison. *The Changing Demographic and Economic Structure of Nonmetropolitan Areas in the United States.* R-2399-EDA, Rand, 1979.

Morrison, Peter A. *The Transition to Zero Population Growth in the Midwest.* N-1167-NICHD/EDA, Rand, 1979.

Ryan, Vernon D., Brian F. Blake, Ralph M. Brooks, and John R. Gordon. *Community Size Preference Patterns Among Indiana Residents: Implications for Population Redistribution Policies.* Purdue University Agr. Exp. Sta. Res. Bull. 55, September 1974.

U.S. Bureau of the Census. *Current Population Reports,* Series P-20, No. 331, 1978a.

Wardwell, John M. "Equilibrium and Change in Nonmetropolitan Growth." *Rur. Soc.* 42(1977):156–179.

Williams, James D., and Andrew J. Sofranko. "Motivations for the Inmigration Component of Population Turnaround in Nonmetropolitan Areas." *Dem.* 16 (1979):239–255.

Zuiches, James J., and Glenn V. Fuguitt. "Residential Preferences: Implications for Population Redistribution in Non-metropolitan Areas." *Population, Distribution, and Policy, Part V.* Washington, D.C.: The Commission on Population Growth and The American Future, 1972.

———. "Residential Preferences and Mobility Expectations." Unpublished paper presented at American Sociological Association meeting, New York, Sep. 1976.

Zuiches, James J., and Jon H. Rieger. "Size of Place Preferences and Life Cycle Migration: A Cohort Comparison." *Rur. Soc.* 43(1978):618–633.

Modeling Rural Growth

Clark Edwards

Rural economic growth has been in and out of the spotlight as a public issue. Sometimes the concern is how to spur lagging development. Sometimes it is how to limit an unbalanced surge. Other times interest lags and the issue is neglected. When the issue is in the spotlight, there are always ready answers at hand to the question, "What to do?" During the 1960s we often heard: "Stop rural outmigration or reverse it!" Toward this end, we made loans and grants, trained workers, and located firms. The answer by some persons in areas which were growing too fast during the early 1970s was to put up a sign to the effect that "this is a nice place to visit but we don't want you to live here."

Policy makers have identified the issue. And they have many ready answers. What they are frequently missing are the economic reasons which relate the answers to the issues. That is where we, as researchers in agricultural economics, come in: we can help provide the kind of understanding of the issues that comes from research, and which serves as a basis for policy prescription. The point of this paper is that, although we have been performing this function, we are not doing it as well as we might. Our research provides helpful descriptions and useful projections, but our models generally are not reliable for predicting impacts or for calling turns.

This paper addresses three obstacles to modeling rural growth: models, data, and theory. Some of the obstacles are inherent in the way we approach the modeling process; some are attributed to limitations of available data; and others stem from failure to incorporate relevant theory.

Models

The idea of economic modeling brings to many minds visions of mystifying mathematics, dreary data, and cold computers. Of course not all models are mathematical, empirical, and computerized. But let the image stand—let us talk about that kind of model. One important obstacle to building models is that many people simply oppose them. And their grounds for opposition have some validity. They say, for example, that one cannot capture the things that really count in economic progress—the quality of life and a sense of well-being—in a numerical measure or in a computerized system of equations. To many, getting a region to grow is a practical problem unrelated to mathematics. Certainly, negotiations by community leaders to locate a plant employing 500 persons is not a problem in mathematics. And secondary employment induced as a consequence of locating this plant can be calculated with simple counting methods that can hardly be considered mathematical.

"If such problems can be understood in plain English," so the question often goes, "why do we need to treat them mathematically?" The wish to have our models explained in plain language is a reasonable one. It is hard for a researcher to explain that a simple translation of a mathematical model into English is not possible. The mathematical and computerized model is not merely another language, it is also a logical system. The analogy might be that the model translates not into a sequence of simple sentences, but into a syllogism. The model imposes a system of organized reasoning. The reasoning can be understood from ordinary language if one makes a special effort to follow it. But most of us do not think in perfect syllogisms, and the reasoning is likely to be lost when each equation is translated into language.

Maybe if we knew enough about economic growth we would not need to turn to mathematical and computerized models to evaluate alternative policies; we would know by experience what the impacts of each policy would be. But most of us do not know that much. So we make up for it by using models to organize our thoughts and to reason out the

---

Clark Edwards is a senior economist with the Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture.

likely consequences—either quantitatively or qualitatively—of alternative actions. The gains from organized reasoning need to be compared with costs such as that of reducing to numerical measures certain human values that are properly understood as not numerically measurable.

Let us assume that the trade-off favors modeling and inquire into other obstacles to modeling rural growth that are evident in published research.

Cause or Effect

One common empirical method to identify factors affecting area growth is to sort the data according to the intensity of the problem and then note associated factors. For example, we can rank the 3,000 counties according to rate of growth in population and then notice that slower-growing counties exhibit, say, a lower average level of education than faster growing counties. The beauty of this method is that it always works. There is always a group of slower-growing counties, and such a group can always be found to have certain distinguishing characteristics. This is what makes the method descriptively useful. However, it is not analytically useful to sort on the effect and then notice the cause. If we seek to explain, we should sort on the cause and notice the effect. In this example, we should sort on level of education and test whether counties with lower levels of education are significantly slower-growing.

One reason we persist in doing the thing backwards may be that it requires less thought; in one pass on the computer one may, mindlessly, catch several "explanatory factors" that are statistically significant. To order the data causally, one must think ahead and either do more detailed cross-tabulations or make more computer runs. Another reason may be that it is easier to explain anomalies when we do the thing backwards; it is easier to explain as an exception to the rule a slower growing county with a high education level than a county with a low education level which grew rapidly.

Recent statistical tests of causality, based on an operational definition of the concept, may help us to sort out, at least in a statistical sense, what is cause and what is effect in economic growth, and thereby improve our ability to model causal structures.

Simple or Complex

Many rural growth models are exceedingly detailed and complex. The driving idea behind them appears to be to build a model comprehensive enough to be capable of answering any question which might arise. Of course there are certain economies in building models which are large enough and general enough to warrant repeated use. But there is a tendency to go too far and build models which bog down in their own mathematical complexity and their detailed data requirements. Some detailed models, such as input-output, have large data requirements but follow simple logic; they are therefore easy to understand although expensive to construct. Others, such as simulation, may have simple data requirements but follow complex logical relationships that are exceedingly difficult for a user to understand. One ridiculous equation inadvertently embedded in a large simulation model might never be discovered either by the builder or the user. The high probability of such accidents leaves one concerned about building models more complex than necessary.

At the other extreme, some of our models are entirely too simple to capture the complexities and the many facets of economic growth. Almost all single-equation models are suspect because they cannot allow for simultaneous determination of growth variables or for feedback and reciprocal relationships.

Between the extremes of too big and too small, there must be a size which is just right. One approach to determining model size is this: start with the problem you seek to explain, say rural economic growth, and write down the variables with which you intend to explain it, say population, income, and employment. If it requires three variables to describe the situation, then a minimum of three equations is needed; if the results of a model are to be summarized by these three variables, then fifty or a hundred equations are far too many.

But there is a good argument for using more than three. If you can explain population with one equation, you can usually do it better by explaining a few of its major components with separate equations. For example, two equations, one for working age people and another for dependent oldsters and youngsters, can be expected to give better results than a single population equation. Using this rule, a minimum of six behavioral equations will be

needed for explaining two categories each for population, income, and employment. And three identity equations will be needed to form the totals of each variable. A nine-equation model, then, can adequately explain the stated problem. And a model of ninety equations is not likely to do any better job than one of nine or so in explaining the three variables of concern. Worse, unless a priori totals are incorporated to constrain the ninety equations and keep the results "in the ball park," the larger model is likely to behave less well than the smaller one.

Some obstacles to modeling rural growth would be overcome if we gave more thought to (*a*) the problem the model is intended to solve, (*b*) the variables actually needed to describe the problem, and (*c*) the minimum number of equations needed to adequately explain the essential variables.

Seek Answers or Assume Them

Many models assume answers to questions to which their prospective users are seeking answers. For example, a rural growth model may assume a target population, and perhaps a target level of income, for the year 1990, and then examine the industry mix and resources that would be required to realize the target. There is nothing wrong, of course, in building such models; they are useful. The error arises when the user (and sometimes even the model builder) classifies such a model as a growth model. If a model assumes the level of growth as an input, it is not useful for explaining growth.

Describe or Explain

Many of our mathematical, empirical, computerized models are thought to explain growth when they really only describe it. Descriptions are useful, but they are not explanatory. Stages of growth models describe various stages through which a region is expected to pass without explaining how the region moves from one stage to the next. Shift share models measure the extent to which unique regional factors contributed to growth without identifying what the unique factors were or how they contributed. Projections models describe the likely future based on recent trends. Some of the methods of projection are complex and ingenious but, analytically, they have no more explanatory value than linear extrapolations. Descriptive models can influence decisions by policy makers. But they do not constitute models of growth. They are not capable of forecasting a turnaround. Nor are they capable of being used for evaluating the consequences of policy intervention or for assessing alternative futures.

Data

Major gaps exist in the data base for rural growth models. There are several causes of these gaps. Some data which have been available for a long time, such as for farm employment, are considered obsolete because demands on the data have changed while the supply has not. Some series we would like to use, such as adequate measures of underemployment or hidden unemployment, are not supplied. The reporting units on which data are made available often do not correspond to the analytic units in our models. For example, the data may pertain to establishments (place of work) whereas we want to model families (place of residence). The time detail is often wrong. We have one census for 1970 and will have another in 1980. But families in the 1980 census will not be linked to families in the 1970 census for longitudinal information. And comparable information for intercensal years will not be available to study the turnaround in rural growth exhibited during the late 1960s and early 1970s.

Rurality is a geographic concept and lack of geographic detail in published data is probably the most important source of data gaps with respect to rural growth analysis. Even though many of the geographically specific data needed are collected in various censuses and surveys, this gap continues because such data are generally not released by the data collection agency in sufficient geographic detail.

Data are relatively more or less reliable depending on the number of observations underlying a reported average and on the accuracy with which released data are edited. Several data gaps result from the way the present data system has been conceptualized. For example, much of the industry detail available for rural growth models describes product markets, whereas a growth model may need detail on factor markets instead. Because of increased institutional size, economies of scale, and specialization, the separation of data suppliers from data users has created data

gaps which could be narrowed by means of better communications among institutions.

Some data gaps are formidable—their resolution would not be cost-effective and we must learn to live with them. Others can be narrowed at nominal (virtually zero) cost by making small changes in the way some data are collected and reported. Researchers all too often adapt their models to accommodate existing data series. Sometimes a far better solution would be to become more aggressive about insisting that needed data become available.

Some ingenious procedures are being developed by researchers for getting around data gaps without waiting for perfect data and without sacrificing the logical content of their models. Let me give two examples: one is to use primary data insofar as they are available or considered absolutely essential, and to use inexpensive and readily available secondary data sources as default options when primary data are missing. Another is to merge two files (which together have the required information, but which separately do not) into a synthetic, comprehensive file. The direct benefit of these procedures is to maintain operational models. A fringe benefit is that the results can be used to estimate the benefits that would likely follow from collection of more primary information and more comprehensive data sets.

Theory

Theory allows us to explain economic phenomena. To understand and influence the course of rural economic growth, economists first need a growth theory. Alternative futures can be examined, causes can be understood, and intelligent choices can be made. At one extreme stand those whom William James called the tender-minded; they seem to believe that pure theory alone is all that is required to solve problems of economic growth. At the opposite extreme stand those whom he called the tough-minded; they seem to believe that hard facts alone are required. As for the rest of us, we seek to ground empirical models in appropriate theory. The theories we need are scattered through economic literature. Until these have been merged into a single, comprehensive theory, modelers must chose eclectically. In such an environment, the likelihood that any single model will incorporate all relevant theories must be very low indeed.

The various growth theories can be, and have been, collected and discussed in ordinary language. And the theories have influenced practitioners in community development. But integrating them all into a consistent set of equations which function as a growth model is exceedingly difficult. Obstacles to incorporating some of these disparate bases for growth into a single, comprehensive model are the subject of the remainder of this paper.

Increasing Resource Availabilities and Improving Technology

Neoclassical microeconomic theory incorporates two bases for growth. An increase in output results either from using more resources or else from obtaining more output per unit of resource. These two microeconomic ideas so completely dominate our thoughts that when they are presented in the growth chapters toward the back of our macroeconomics textbooks no one appears to notice a contradiction: models which assume that all savings are invested, that supply creates its own demand, that there is full employment, and that money is simply a veil over the economy are introduced in the back of a book dedicated to contradicting these assumptions. Incorporating resources and technology as bases for growth is relatively easy and is frequently done. So let us assume we have a growth model incorporating these two ideas and inquire into the difficulties encountered in adding other bases for growth.

Expanding Markets

The idea that aggregate demand is a basis for growth has three roots. Classical ideas about the importance of foreign trade embrace the concept. And Keynesian theories center on the importance of demand. Economic base theory is at times interpreted as a simplified, one-sided version of either of the above, but is at other times considered to have an independent origin. As far as construction of economic growth models is concerned, economic base theory and Keynesian macroeconomic theory are very much alike. Each model is driven by demand rather than by the neoclassical bases for growth—resources and technology. And each incorporates multipliers

which measure secondary impacts. Models for rural growth which are driven by demand abound. The obstacle to growth modeling of concern here is encountered when efforts are made to merge the neoclassical and the Keynesian ideas into a single model. The ideas are seen to be, on the face of it, incompatible. Let me illustrate how this is so.

Consider two ways that an input-output matrix can be used. Using Keynesian logic, we can start with a menu of final demands and inquire into the industry mix and resources required to produce it. If there were idle resources, the economy would grow as demand grew. On the other hand, using neoclassical logic, we can start with a menu of resource availabilities, incorporate the input-output matrix into a linear programming format, and inquire into the industry mix that would maximize final product. In this case, the economy would grow as resource availabilities and technology grew. Now ask yourself how to get a model to behave both ways at once. The answer lies in building in some kind of a flip-flop mechanism so that causation flows in one direction through the input-output matrix when resources are slack and in the opposite direction when they are fully employed. If some resources are slack while others are fully employed, it gets even more complicated. So let us simplify the problem further.

Consider a growing economy which can be described by two variables: an input and an output. There are three equations: a demand for output, a supply of input, and a production function. This system is overidentified: three equations for two variables. The neoclassical solution is tantamount to assuming that the demand relation is an inequality—that there is an effective demand for at least as much as will be produced when resources are fully employed. This is accomplished by Say's Law. The Keynesian solution is tantamount to assuming that the supply relation is an inequality—that production capacity is adequate to produce at least as much as will clear the market. That is, only two equalities are needed to determine the system's growth—one pair if demand is the basis for growth, the other if resource availability and technology are the bases. A consistent clue as to which is which is in the production function. If the model is demand driven, the logic flows through this function from output to input. If the model is supply driven, the logic flows in the opposite direction, from input to output.

In a comprehensive model, there must be inequalities describing demand and supply and a flip-flop mechanism describing the direction of flow of logic through the production function. One obstacle to modeling rural growth is to figure out how to make our models consistently incorporate both Keynesian ideas of demand and neoclassical ideas of supply in a comprehensive and consistent system of equations.

Conquering Space

Rurality is a geographical concept, yet many rural growth models fail to incorporate spatial relationships. We should be able to display the results of a rural growth model on a map. The obstacle here is not only redesigning the logic among variables already in the model as was required above, but also to incorporate overlooked variables. There are four categories of flows over space to examine: people (migration and commuting), goods (imports and exports), capital (balance of trade), and ideas (diffusion of information). Other variables already in the model must be identified by location. The logic of the growth models must be redesigned to incorporate opposing forces which induce centralization and decentralization. Centralizing forces are identified by central place theory. They include agglomerative efficiencies and transportation costs. Decentralizing forces include rent gradients and von Thunen rings. Spatial bases for growth are ignored in most of our rural growth models.

Institution Building

Econometric models have tended to capture short-run phenomena by assuming that needed institutional arrangements were in place. Longer-run issues, which were harder to model, were abandoned to the institutional economists who knew that institutional change does matter and knew how to account for it in economic analysis. Now that we have learned to build dynamic models that cover economic change over time, the importance of integrating institutional economics with econometrics is reemphasized. This situation is giving rise to a new breed of institutional economists who are trying to capture the essence of institutional relationships as equations in econometric models.

Two aspects of institutions are fairly easy to capture. First, one function of an institution is

to assess ends or goals. These goals can be written as equations—maximizing gross regional product, minimizing unemployment, and improving the distribution of income, for examples. Institutions help to resolve conflicts among goals; models can be used to exhibit trade-off possibilities among competing goals.

Second, institutions promulgate behavioral rules. These rules can be written as equations. Some examples, such as tax laws and price support levels, are commonly incorporated and recognized as institutional constraints. With imagination, we can capture more institutional rules, for examples, zoning laws, water rights, and licensing requirements.

Other aspects of institution building are harder to capture. Institutions are groups of people acting toward certain ends. How do you capture in an equation a group of area planners acting to promote regional growth? If they change a zoning law or an objective, we can change an equation. But this is ad hoc and likely to miss the essence of a planning organization. Some of it might be captured with a zero-one variable which opens certain synapses among economic variables when the institution is present and closes them in its absence.

Each of the several bases for growth discussed above—resources, technology, markets, space, and institutions—can be, and have been, incorporated in rural growth models. Many models incorporate two or three. A few contain four. I have yet to see one that satisfactorily reflects all five. And I think there is good reason for our failure to do so—it is not easy. But I see it as a challenge which we as a profession need to work on.

Conclusion

A number of models of rural growth have been built and used by agricultural economists. Clients use the results. There is a demand for more and better policy guidance on strategies for rural growth. I have given my reasons for thinking that we are not modeling rural growth as well as we might and that, consequently, we are not providing, as well as we might, the economic reasons which connect policy prescriptions to rural economic issues. I have offered my suggestions about how we, as researchers, can improve our rural growth models. The ideas we need are lying about in the literature—but we have not put them all together yet.

Rural Employment and Rural-Urban Population Shifts: Discussion

Brady J. Deaton

The topic under discussion directs our attention to a major demographic shift unparalleled in modern history. We should note that Western Europe, Canada, and several developing countries are also attempting to deal with urban-to-rural migration and/or declining rates of rural-to-urban movements. So, we are observing a cross-cultural phenomenon of migratory decision making which is constrained by economic realities.

Edward's paper addresses the applicability of economic models to the problems associated with rural employment and population shifts. His assertion that "we should sort on the cause and notice the effect" assumes that we have identified the problem, specified a conceptual model, and can properly measure the relationship between cause and effect. In reality, we often fail in one or more of these efforts. I prefer a problem-oriented focus which forces us to examine alternative dimensions of both cause and effect. From Dillman's paper, I infer that the persistent value placed on rural over urban amenities has finally been recognized by corporate decision makers. Consequently, an increasing number of manufacturing plants are located in rural areas where production costs are lower, workers happier, and profits higher. By way of division of labor, I will be directing the balance of my comments to Hoch's paper.

Hoch's topic was challenging, his concluding hypothesis stimulating, but his approach may be most useful in pointing to some limitations of data and modeling. I was frustrated in trying to come to grips with the theoretical underpinnings of his approach. While his paper reflects intimate familiarity with the broader issues, I fear that sufficient guidelines have not been provided to enable the reader to identify effectively and evaluate the basic information flowing from his analysis.

Hoch recognizes that wage differences among locations may arise from diverse causes, including (*a*) heterogeneity, (*b*) disequilibrium, and (*c*) compensatory payments. His analysis of each cause will be briefly discussed.

Heterogeneity: Hoch defines compensatory payments as wage differences which arise from the disutility associated with larger size communities. That is, compensatory payments are the residual wage after heterogeneity and disequilibrium are accounted for. In order to measure the relationship between compensatory payments and population size, heterogeneity is controlled only by selecting two groups in the work force, female clerical workers and farm laborers. A strong argument could be made that these groups are also quite heterogeneous. A dairy farm worker may not represent the same set of skills and wages as either a tobacco cutter or a pea picker.

Nevertheless, if this selection is accepted, then conclusions should apply only to female clerical workers and/or farm workers. Yet, Hoch reaches rather profound conclusions for all rural workers and rural communities and goes well beyond the strength of his data in the process. For example, he asserts that "the wage-population size relation appears to hold for rural occupations and for nonmetropolitan settlements, as well as for their urban and metropolitan counterparts." At another point he concludes that "minimum disamenities occur in the 10–25 thousand range, making that population level 'optimal' in terms of preferences." While Hoch warns that this hypothesis needs intensive testing, his conclusions are not warranted by the limited data analysis.

Disequilibrium: This topic is addressed indirectly by observing a downtrend (16% to 13% per order of population magnitude) since 1972 in the size of the regression coefficient of population associated with deflated per capita incomes. Hoch concludes that "people in smaller places currently are receiving more

Brady J. Deaton is an associate professor, Department of Agricultural Economics, Virginia Polytechnic Institute and State University.

than is needed to keep everyone in their place, so there is net migration from larger to smaller places." This line of thinking is all based on the implicit notion that observed wage differentials are primarily due to compensatory payments.

On the other hand, the observed changes in regression coefficients could be explained by other more theoretically appealing factors. For example, product prices for most manufactured goods are probably relatively homogenous across rural and urban points of origin. Therefore, the ability of urban manufacturing plants to provide higher compensatory wage payments is quite restricted by competing products produced at lower cost in rural areas. Urban wage flexibility decreases as a larger proportion of manufacturing production originates in rural communities where money wages are lower while product prices are spatially constant. At the same time, an urban-to-rural labor flow places increased wage pressure on urban plants.

The continuing decentralization of manufacturing plants into rural areas strengthens this interpretation. A continuing set of new equilibrium conditions are being established by the changing economic environment. There are no "good old days" of equilibrium around 1972 conditions that we should be yearning for or expect to see again. Wage differentials will probably continue to decline as both capital and labor flows adjust, along with changing technology, preferences, and nonpecuniary diseconomies of scale. The pervasiveness of these dynamic conditions have not been addressed adequately by Hoch. Simply stated, compensatory payments may be part of the reasons for the observed differentials, but are certainly not the full picture. Hoch has not shown us how important they are, nor given any idea of their magnitude.

Compensatory payments: I agree with Hoch that "people will tend to shift to places offering lower money wages but equal real wages, relative to alternative locations, since this will increase real disposable income." Migration streams, particularly urban-to-rural streams, are composed of a complex mix of those who experience income increases as a result of the move; those who are rejected by, or cannot adjust to, the urban work environment; and those who give up higher incomes to enjoy the nonpecuniary benefits of rural life (Deaton and Anschel). Hoch's analysis is primarily concerned with the latter, though he does not draw these distinctions. This issue has profound implications for rural development if it is properly measured and interpreted within a theoretical framework that helps provide direction to our thinking.

For example, I could see the notion of compensatory differentials being linked directly with Kaldor's theory of cumulative causation where the efficiency wage (money wage divided by a productivity index) declines as productivity increases and propels the local economy along an upward growth path. Compensatory wages suggest that the money wage will not be equal as Kaldor assumed, but will be lower for rural areas. The combination of relatively lower money wages and relatively greater productivity provides a "super accelerator" for rural community growth which is consistent with conditions associated with the population turnaround. This approach would provide a foundation for assessing the interrelationship between money and real wages and their linkages with varying productivity levels.

In conclusion, Hoch's work illustrates how far we are from the integrated-modeling approach that concerned Edwards. The lack of a fully integrated model, however, does not keep us from rigorously applying economic concepts and statistical techniques to important rural development problems. The theoretical links between a number of observed effects and reasonable causes may not be amenable to easy measurement even if they are conceptually distinct. However, we can all benefit by reviewing Bonnen's insistence on the rigorous process that transforms mere data into meaningful information. We have seen some of each in this session and should be challenged to apply more rigorous methodological procedures to this issue.

References

Bonnen, James T. "Improving Information on Agriculture and Rural Life." *Amer. J. Agr. Econ.* 57(1975):753–63.

Deaton, Brady J., and Kurt R. Anschel. "Migration and Return Migration: A New Look at the Eastern Kentucky Migration Stream." *S. J. Agr. Econ.* 6 (1974):185–91.

Kaldor, Nicholas. "The Case for Regional Policies." *Scottish J. Polit. Econ.* 17(1970):337–48.

Rural Employment and Rural-Urban Population Shifts: Discussion

Ron E. Shaffer

The three papers in this series focus on why we have had a rural shift in population growth or "rural turnaround." The Hoch paper suggests that the movement of people into rural areas is a rational choice based on economic criteria, even though the rationality may not be readily apparent. The Dillman paper indicates that individuals' nonmonetarily motivated residential location preferences are a very important force in settlement patterns. These preferences may be contradictory to prevailing economic signals. The Edwards paper discusses our conceptual tool-kits to understand and analyze these types of trends, and the obstacles to testing empirically these conceptual ideas.

The papers fail to address what effect the gas shortage and gas prices will have on the marginal rural in-migrant. How strong is the desire to live in a bucolic setting? How many people remaining in metro areas are going to move to adjacent areas or even nearby exurban developments? They did not move before under more favorable conditions. With higher gas prices and unavailability, will they fill the metro out-migration streams? Will jobs follow people to rural areas because the energy cost to society of smaller scattered production units is less than that for concentrated production sites? I believe these critical and still largely unanswered questions will affect the continuation of the rural turnaround. Yet, these papers utilize now questionable historical data to hint at the future trends.

Hoch suggests that comparisons of income differentials require consideration of the following three forces: first, the heterogeneity of the resource base and the economic structure of the areas compared; second, the presence or absence of compensating payments for market- and nonmarket-related cost-of-living adjustments; third, that differentials may signal market disequilibrium and imply a need for resource movement. After reading the paper, I am still convinced that these forces need to be considered, but the author has failed to give me much insight about which has been, and is likely to continue to be, a dominant force in the rural turnaround.

Hoch suggests that people will continue to move to rural areas and accept lower money income because inflation-triggered tax bracket jumping will, in effect, reduce their disposable income. This idea deserves some study, although I believe the effect is minimal. I sense that people are moving to rural areas and accepting lower wages not because of income tax burdens or an implicit income tax windfall, but because of the nonmonetary factors that increase their real income as Dillman's paper suggests.

Dillman shares a compilation of factors that have been suggested as being causal to the population turnaround. Some of these factors are quite likely to continue into the future, but others are not or their influence may even be reversed. Let me mention a few of the specific factors likely to change. Number 7: Increased enrollment in nonmetropolitan colleges and universities is likely to be less of a force as the age structure of our population changes. An additional dampening influence is the budgetary constraints facing higher education. Number 8: The growth of state government is likely to be less of a force as the "Proposition 13" syndrome is felt either explicitly or implicitly in governmental activities. Number 12: More long distance commuting may be completely reversed, depending on how people react to the cost of gas or even its total unavailability. Will we make adjustments through vanpooling and light-density mass transit systems or will there be a movement back into more concentrated settlement patterns? Number 15: The lower cost of living in rural areas may disappear as the cost of energy and housing approach that present in many urban areas. Number 16: Lower crime rates may also be a historical artifact, given the current concern of

---

Ron Shaffer is an associate professor in the Department of Agricultural Economics, University of Wisconsin-Madison.

local officials and citizens in many rural areas about the dramatic increase in crime in those areas.

Probably the most interesting point in the Dillman paper was the different motivations for moving to nonmetro areas and among nonmetro areas. The movement to nonmetro areas is nonemployment-oriented, somewhat in agreement with Hoch's conclusions. However, the movement among nonmetro areas was employment-oriented.

The alarming statistic about the movement of people back to smaller communities is their desire to live outside municipal boundaries. This holds long-run implications for land use, farming-residential use conflicts, and provision of municipal services.

The Edwards paper discusses our inability to incorporate the diversity of factors that affect rural economic growth into precise mathematical models. While I agree that we have been unable to generate precise, comprehensive, and mathematical models of rural economic growth phenomena, I believe we have made some significant advances. Our mathematical modeling abilities have not kept pace with the practitioners. Granted, practitioners have not been able to synthesize their ideas in journal articles, but if you listen closely to what they say, there is a realization of the comprehensive approach required.

The caution about labeling many of our projection and descriptive models as growth models is an issue that deserves attention by many in the profession.

There is much truth in the contention that we must be eclectic in our selection of tools and theories. While we have not been able to achieve a comprehensive community growth model, this does not mean that the rigor of the analysis is anything less for specific community situations. It may be that we need to remind people of the uses and limitations of our theories and caution them about the conditions that make their use appropriate or inappropriate. The synthesis of a comprehensive theory can remain as our long-run goal, and more appropriate use of existing theories and tools remain a legitimate short-run goal.

In summary, a careful reading of the papers reinforces the belief that while our understanding of the rural turnaround has improved, there are still substantial gaps in our knowledge. This is especially evident in the transferability of this knowledge into policy prescriptions.

Nutrition and Food Policy
(Sylvia Lane, University of California, Davis, Chairperson)

The Segments of the World Population at Nutritional Risk

Leonard Joy

I find it useful to distinguish four aspects of "the problem of malnutrition": (*a*) the existence of people currently malnourished, (*b*) the existence of people in situations which are characterized by an unacceptable risk of malnutrition, (*c*) trends and forces which increase the numbers at risk of malnutrition, and (*d*) lack of sensitivity and/or effective response of society to the above realities. The four corresponding tasks include: (*a*) the identification and treatment of the malnourished, (*b*) the reduction of the number of people exposed chronically to the risk of malnutrition, (*c*) reducing or offsetting those forces which make for increase in the numbers at risk of malnutrition, and (*d*) improving the sensitivity and responsiveness of society to nutritional deprivation. While I frequently use this fourfold breakdown, I am constantly reformulating it. The present version is not offered as in any way definitive. This paper discusses aspects (*b*) and (*c*), though its concern is strongly with (*d*), the lack of society's sensitivity and effective response.

Those Currently at Risk of Malnutrition

We conceivably might seek to identify all those individuals currently at risk of malnutrition. Indeed, some programs do just this. They use some criteria for determining who gets food stamps, or a ration card, or food for work. The criteria used typically include socioeconomic, demographic, or locational criteria which define categories of people believed to be in need and which provide tests of whether specific individuals are to be counted in the categories so defined. In practice, the criteria used are varied and situation specific. An answer to the question: "Who are the people at risk of malnutrition?" might therefore be in the form: "People who meet the following criteria. . . ." Or, "People in the following categories: . . . ."

But how do we discover what these categories are? As ever, we can make observations and develop theories using each to prompt, test, and refine the other. An interesting example of such a process and of its product is one that was carried out in Bangladesh (Currey). Here the attempt was made to identify administrative units (*thanas*) with a high famine risk. *Thanas* were assessed in terms of characteristics which can be seen to be either (*a*) risk of trauma (drought, flood, cyclone, and river erosion), or (*b*) characteristics which make for lack of resistance to trauma (population pressure, food supply deficit in normal years, lack of alternative employment, low crop yields, inaccessibility, and unreliable farm input supply system). Some *thanas* are shown to be exposed to more than one class of risk and to have several characteristics which make them nonresistant to shocks or less able to recover from them. The application of this classification shows a varied pattern of constellations of problems calling for equally varied responses. What this classification does not do, however, is to identify which categories of people or households within each of the vulnerable *thanas* are vulnerable. Nor does it, therefore, reveal whether there is a need for a variety of responses to meet specific classes of individual or household situations. Also, it does not reveal that there are some people at risk even in *thanas* which are not, overall, classified as vulnerable.

Leonard Joy is a visiting professor of food and nutrition policy analysis in the Department of Nutritional Sciences at the University of California, Berkeley.

The author would like to express his appreciation to Irma Adelman and Ritva Kaje for the valued comments on this paper.

Clearly, the basis chosen for classification determines whose risks are attended to and whose neglected, which categories of risk are differentiated, and which are lumped together. Clearly, too, the basis for categorization may be operationally congruent with some administrative and organizational patterns and incongruent with others. What this implies is that we need to design classifications which relate to specific administrative structures and to management rules designed for responding to actual or threatened traumas.

In general, however, our response to the existence of at-risk populations will take the form of (*a*) measures to reduce the risk of the trauma to which they are exposed (drought, flood, disease, unemployment, fall in real incomes, etc.), (*b*) measures to make them less vulnerable (improve normal nutrition status, increase wealth and income, stabilize food supplies and prices at desirable levels, strengthen or augment social support mechanisms, crop insurance, etc.), and (*c*) measures to speed recovery (relief and rehabilitation measures). Thus, our tasks are: to determine the nature of the trauma faced by different people; to explore how the threat of trauma might best be reduced; to find ways of increasing people's capacity to withstand trauma; to design a system for responding appropriately and effectively to specific threats and experiences of trauma.

In reality, however, the method of inquiry commonly used in planning for food and nutrition goals does not encourage this. Typically, the focus of investigation and analysis is on nutrition status, the identification of specific nutritional disorders, and the quantification of their incidence and prevalence. This generally is attempted by means of sample surveys of total populations which relate anthropometric and biomedical observations to such demographic and socioeconomic data as family size, income, and environmental sanitation. However, these may not be efficient or even necessary data for understanding the risks to which people are exposed or for the design of appropriate action. Also, prior to the collection of data, we need information in a form which may not be readily processable. Especially, we need stories about people's conditions and how they got that way. We need to know what traumas threaten people and how people react to trauma. From this we might learn what might be done to prevent or mitigate the shocks which result in malnutrition. Different things might need to be done by or for different categories of people. In order to generalize and to design appropriate measures it may be important to know the incidence and prevalence of different categories of people and risks. Thus, surveys may be called for. But the sampling frames and content of surveys used as part of such an approach are likely to be very different from those of the conventional nutrition survey. Generally, too, they will also be designed after we have gained an understanding of what needs to be done rather than in order to gain such an understanding.

Trends in the Numbers at Risk

If we succeeded in identifying all those at risk and took steps to reduce their vulnerability, we might discover that the numbers of those "at risk" continued, nevertheless, to increase. In general there seems to be good reason to expect trend increases in the numbers of those at risk. In order to predict the numbers, and categories, of those who will in future be at risk we need to be able to conceptualize and analyze the system which generates people who are nutritionally at risk. We need to know not only what categories of people are at risk, but also what it is that puts people into these categories. Again, understanding requires both observation and theorizing. My own observations produce some repeated scenarios: families who have inherited, or will inherit, too little land on which to survive; landless families or sharecroppers displaced from reliable dependency on a landlord by a new technology or market opportunities or by the availability of cheap casual labor or by landlord's attempts to avoid land reform legislation; and rural or urban migrants, jobless and no longer able to rely on the support of their families or patrons in distant villages or to follow their families' previous way of life. It is among such people that malnutrition—both chronic and episodic—is especially to be found.

Such observations as these can be refined, tested, and used for theorizing to provide the basis for the design of action. What is needed is an effective conceptualization of the processes which generate economic and social displacement of the sort described above. (I use the word displacement because I am talking about people who cannot find a place in economy or society.) Attempting to build

models of the "displacement" process is a good way to check observation and analysis against each other. It is also, perhaps, essential to providing an understanding of where the behavior of the socioeconomic system might be modified to reduce the unwanted results.

Figure One illustrates a proposal for a system conceptualization of the processes that generate households which are unable to provide reliably the means of their own subsistence in the Machakos District of Kenya. (A comparable formulation conceived with North India in mind can be found in Joy and Payne.) This tentative formulation could be of value, even in its present form, as a presentation with which alternative system conceptualizations might be compared. It provides the basis for a dialectic to improve our understanding of those forces which are most important in generating malnutrition and of how we might intervene to modify their workings. It could also be quantified and used for computer simulation—either of the system as a whole or of some of its subsystems (e.g., land allocation mechanisms, the rates of creation of new households and the factors governing these, local/temporary casual labor migration, technological change, impact mechanisms, etc.). Whatever the level of quantification or complexity used, these simulation models are essentially nondisciplinary. They do not confine themselves to the questions or variables of any one discipline. They attempt to model systems which generate the phenomena that we wish to control. The systems thus modeled are defined by these phenomena and the state variables by which we choose to measure and observe them.

The choice of state variables is critical. (For a discussion of some models which do not use malnutrition as a state variable, and of their usefulness in policy making, see Joy, pp. 114–18.) It will be noticed that in the example shown here nutrition status is modeled directly. However, it might be appropriate instead to use "displacement" as the state variable defining the system to be modeled (or the assumption that "displacement" is a condition in which the risk of malnutrition is high). If this were done the concept of "displacement" would need to be defined by criteria that are observable, and tested for its relationship to malnutrition. The definition used would need to be specified to suit particular contexts and described by characteristics capable of quantification. These specification tasks should promote reflectiveness about the true nature of the concern which gives purpose to our modeling and about the performance criteria appropriate as the signals to which the management of social action should respond.

Apart from their general value in providing a systematic framework for analysis in the design of social action there are many particular applications of such modeling which could sharpen policy analysis. Models could be run to explore alternative possible scenarios, to learn how, and by what processes, possible events—controllable and uncontrollable—might affect these scenarios (for example, with reference to weather patterns, technological innovation, different levels of population growth, specific demographic changes such as delayed marriage, specific development projects, changes in customs and transactions modes, market forces, etc.). The special value of such modeling is in the understanding it provides about the factors important in determining malnutrition as an outcome of the system. This should greatly sharpen understanding of the sorts of action that will be relevant and effective in pursuing social goals. Moreover, publishing the scenarios that such models generate can stimulate debate about issues and help to improve the articulation of goals. If our concern is to improve society's sensitivity and response to malnutrition, as I think it should be, it is important that those whose actions it is intended to influence should be involved in discussions which are part of the process of model building. This is necessary especially to obtain credibility—to ensure that the realities perceived by decision makers are accounted for in modeling (Johnson). This does not mean involving administrators in the technicalities of model building (Swanson), nor does it mean that models should be no more complex than decision makers can comprehend. (Would that we ourselves could fully comprehend our own models.) The value and influence of a modeling project may not be determined by the rigor or polish of any report in which it culminates, nor by the quality of the analysis, or the "correctness" of its recommendations for policy, but rather by its impact as reflected by improvement in: (*a*) decision makers' articulation of purpose; (*b*) their conceptualization of the system which generates malnutrition (and how it might best be managed and stimulated to secure desired change by those with power, or potential power, to initiate action); and (*c*) the resulting

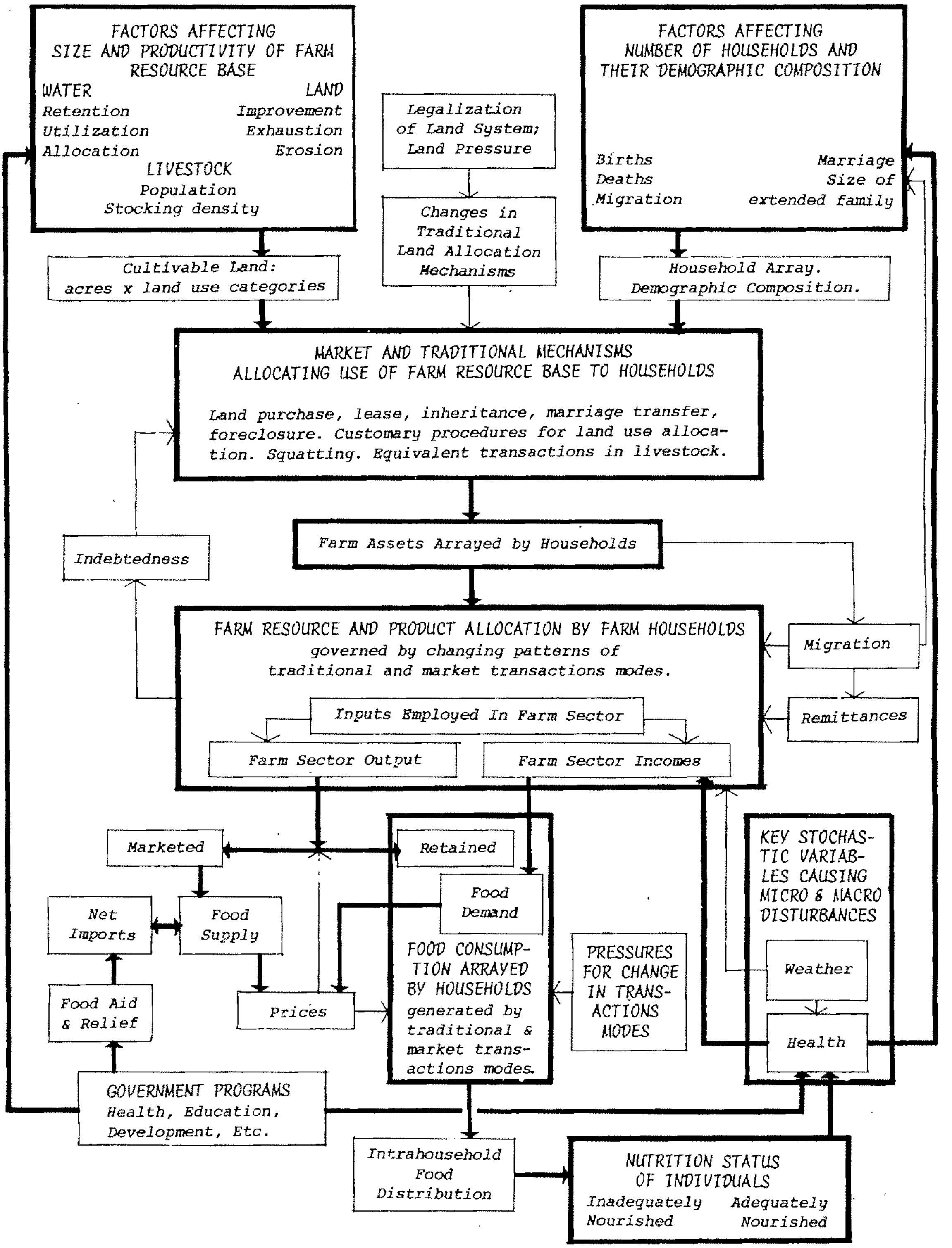


Figure 1. System governing nutrition status in Machakos District, Kenya

action and its effectiveness in securing attainment of desired goals.

Implications

An approach to the design of action to care for those currently at risk would start from an analysis of the capability of specific administrative systems in terms of their sensitivity to signals most relevant to warning of the imminence of trauma (flood, drought, unemployment) and of their ability to respond appropriately. This implies analysis of the risks faced by different groups and of their ability to withstand, and recover from, the shocks to which they are exposed. It implies the design of measures, including routinized administrative or community responses, to prevent, cushion, or in other ways reduce the impact of these shocks and of their threat. This is a significantly different approach from, say, that taken by the FAO, UNICEF, and WHO to "nutritional surveillance" (FAO/UNICEF/WHO). It is also different from that taken in the search for projects which "create employment" or "raise farmers' incomes" without discrimination about the needs of people in different low income situations or insight into the significance of vulnerability and dependency as characteristics of poverty and deprivation—characteristics which vary considerably in their specific manifestations and in what might be done about them.

Longer term planning needs to be focused on the process of "displacement," attempting to slow the process, or avoid accelerating it, where mechanisms for absorbing the displaced are inadequate. Specific concern for absorbing the displaced would also be a prime focus of planning in both the long and the shorter terms. This concern needs to be reflected in a broad view of possible actions embracing innovation in social mechanisms—perhaps at the community level. To see the problem, or solution, simply in terms of optimal resource allocation runs the risk of overlooking a wide range of relevant actions.

National strategy would evolve from a process of attempting to incorporate proposed and actual responses to specific local realities and problem perceptions and to reconcile their general equilibrium and dynamic implications. It would attempt to articulate guidelines for the orchestration of many separate, sometimes localized, actions and responses and the multiplicity of objectives to which they are directed. Nutrition goals would need to be reconciled with many other concerns.

Marxists would argue that the above approach would simply secure bandages for social sores which are an inevitable consequence of the capitalist system; that, at best, it would alleviate the worst deprivations, but allow the system to adapt and survive with other basic ills untreated. I am aware of these arguments and understand that, more generally, I appear to make a presumption that a wider and deeper understanding of how our human ecologies generate malnutrition could lead to steps to correct this.

References

Currey, Bruce. Unpublished materials. University of Hawaii, 1978.

Johnson, G. L. "Contributions of Economists to a Rational Decision-Making Process in the Field of Agricultural Policy." *Decision Making and Agriculture*, ed. Theodore Dams and Kenneth Hunt, pp. 25–46. Oxford: Agricultural Economics Institute, Proceedings 1976 ICAE Conference, 1977.

Joy, Leonard. "The Concept of Nutrition Planning." *Food and Nutrition Planning: The State of the Art*, ed. Leonard Joy. Guildford, England: IPC Press, 1978.

Joy, J. L., and P. R. Payne. "A Note on the Logic and Terminology of Planners." *Food and Nutrition*, vol. 1, no. 4, 1975.

Swanson, Earl R. "Working with Other Disciplines." *Amer. J. Agr. Econ.* 61(1979):849–59.

United Nations, FAO/UNICEF/WHO Joint Expert Committee. *Methodology of Nutritional Surveillance*. Geneva: WHO Tech. Rep. Ser. No. 593, 1976.

Estimating Consumption Parameters for Food Policy Analysis

C. Peter Timmer and Harold Alderman

Food policy analysis links nutrition objectives to macroeconomic policies and performance. At the heart of the analysis is a matrix of price and income elasticities that must be income-strata-specific. Obtaining this matrix for aggregated income classes requires a blend of complex theory and sophisticated econometric analysis that is only possible with restrictive assumptions about the separability of the impact of price changes for one commodity class on changes in demand for other commodity groups.

The separability assumptions are not overly restrictive in the context of such highly aggregated commodities as food, housing, or clothing. But when important nutritional effects occur due to substitution of one quality of wheat for another, or the substitution of cassava for rice, then the level of commodity detail needed to reproduce accurately the impact of relative price changes forecloses the "econometric" approach even for combined income classes. Obtaining the full matrix for disaggregated income classes requires a new approach and this paper reports one attempt.

The Consumption Model

Although consumer theory is developed from the decision perspective of an individual consumer or consuming household, it is usually applied empirically in per capita or per household terms to aggregate market data. Thus the opportunity for consumers at different levels to behave differently with respect to economic parameter variation (e.g., changes in prices) which is an integral aspect of the theory, is usually obliterated in the data aggregation process.

Cross-section analysis has been used to understand more about how household decision parameters vary at different income levels. Income-class-specific income elasticities are easy to derive from cross-section consumption surveys, but some care must be used in interpreting such cross-section parameters in a dynamic projection context. The use of cross-section data to derive income-class-specific price elasticities has been extremely limited for fairly obvious reasons. Households are sampled only once at a particular time when the prices they face are given. If the whole sample is taken during a brief period (e.g., one week) then the only price variation observed will be due to spatial differences.

These price differences will by necessity be faced by different households which may have different tastes. In such a situation it is difficult to infer causality to regionally different consumption patterns even when prices are different. The solution to the impass is either to have a cross-sectional panel of consumers whose consumption expenditures are recorded over time or to draw a large sample over enough geographical and temporal diversity to capture significant variance in the relevant variables. Both approaches are quite expensive, but the second does have the advantage of more rapid results if prices show significant seasonal variation. Data from the Indonesian Socio-Economic Survey V (1976)—SUSENAS—used in the empirical analysis reported here capture these effects. With three separate samples of 18,000 households drawn in each trimester of 1976, the sample is large enough so that cell means can be used as observations for analysis. This averages out most individual taste differences, but leaves adequate variations in incomes and prices for statistical analysis. Such analysis can be conducted directly on the raw data when it is accessible by large computers.

C. Peter Timmer is a professor of the economics of food and agriculture at the Harvard University School of Public Health. He also is a faculty fellow of the Harvard Institute for International Development. Harold Alderman is a research assistant in the Department of Nutrition and a graduate student in the Department of Economics at Harvard.

At the level of the individual consumer decision maker, economic theory is quite clear about what economic variables should be included in principle as arguments in the consumption function—own income, all commodity prices, and any factors determining tastes. Given the more than 100 food commodities alone reported by SUSENAS V, inclusion of all prices is clearly not possible. Even with 54,000 observations some aggregation of commodities is necessary to make any sense of the data.

The analysis reported here deals only with rice, fresh cassava, and total calorie intake from rice, fresh cassava, and corn. Attempts to unravel the factors influencing shelled corn consumption alone have not been successful. Because rice, corn, and cassava are the three major foodstuffs for most Indonesian consumers, accounting for more than two-thirds of average calorie intake, whatever functional specification and approach is ultimately chosen must permit accurate estimation of the coefficients determining their use.

Equation (1) presents the standard, general form of a household consumption function.

$$(1) \qquad Q_{ih} = f(Y_h, P_i, P_j \ldots P_z, H_h, T_h),$$

where Q_{ih} is quantity of commodity i consumed by household h (for a given time); Y_h, the income for household h; P_i, the price of commodity i; $P_j \ldots P_z$, prices of other commodities j to z that might influence the consumption of i (significantly); H_h, household size (and perhaps age and sex distribution); and T_h, household tastes (perhaps captured by educational, regional, ethnic, and occupation variables).

The SUSENAS data available for analysis already had converted household observations to per capita terms, and no opportunity existed to investigate the impact of variations in H_h on consumption. Similarly, no educational, ethnic, or occupational variables were available in the provincial level data; only region and urban/rural effects could be specified. The possibility of "taste" changes seasonally was investigated.

Determining a specific functional form from the general specification of (1) is a matter of judgment and empirical fit. Equation (2) shows the general form used throughout this analysis.

$$(2) \qquad Q = A + A_i + a_1 TX + a_2 TX^2 + a_{3_i} P_i + a_{4_i} XP_i + a_{5_j} R_j + a_{6_k} T_k + a_{7_h} D_h + e,$$

where Q is log of per capita commodity consumption in kg. per week for each income class, round, province and urban or rural observation; A, the intercept; A_i, the income class specific intercept; TX, log of total expenditures for respective cell mean observation; TX^2, TX squared; P_i, log of own price of commodity for each observation calculated as commodity value divided by commodity quantity; XP_i, log of cross-price term, calculated as above; R_j, zero-one dummy variable for region j; T_k, zero-one dummy variable for sample rounds January-April, May-August and September-December; D_n, other zero-one dummy or interaction variables, as specified in text; and e, error term assumed normally distributed in logarithms. The Engel function within the overall equation is a double-log quadratic, so that the income (i.e., total expenditure) elasticity of demand for the commodity is specified as $a_1 + 2^{a_2}TX$. Because a_2 is consistently negative for all regression specifications, the income elasticity declines smoothly with higher incomes. A number of alternative Engel specifications were investigated, but (2) gives the best results for the low income observations where our policy interest lies.

Regression Results

The data used in this analysis are cell means reported for twelve income classes for twenty-four provinces (plus Jakarta), separately for urban and rural consumers, for each of three time periods, or approximately 1,800 observations in all. Because the number of households in each cell varied roughly according to its relative frequency in the Indonesian population, all regressions were weighted by the square root of the number of individuals reported in each cell. To avoid the influences of extreme observations due to small cell size, no observation with fewer than ten individuals (approximately two households) was retained. All regressions reported here were run on the entire sample; separate runs by geographic area, by sample round, and by income class are also under investigation.

Table 1 presents the basic statistical results for the rice, fresh cassava, and calories from rice, fresh cassava, and corn regressions. For each of the three categories a general regression is reported (numbers 1, 3, and 5) followed by our best regression with income-class-

Table 1. Indonesian Per Capita Food Demand Regressions (*t*-statistics in parentheses)

	A	*TX*	*TX*²	*UTX*	*PTX*	*PRICE*	*XPRICE*	*URBAN*	*RND* 1
Rice									
Overall									
coefficient	−16.477	4.874	−0.252	−0.151	0.056	−1.163	−0.033	1.207	−0.043
		(12.8)	(11.1)	(3.2)	(2.1)	(8.8)	(0.8)	(3.0)	(1.2)
Income class									
G	−27.69	6.732	−0.347	−0.80	0.114	—	—	1.452	−0.046
		(10.7)	(9.9)	(3.8)	(4.0)			(3.6)	(1.3)
1	6.445					−1.921	−0.073		
	(4.0)					(7.1)	(0.8)		
2	3.971					−1.475	−0.004		
	(2.4)					(4.9)	(0.0)		
3	2.472					−1.156	−0.082		
	(1.8)					(5.1)	(1.2)		
4	—					−0.743	−0.005		
						(4.0)	(0.1)		
Fresh cassava									
Overall									
coefficient	−30.713	6.450	−0.361	−0.140	0.066	−0.893	0.765	—	0.480
		(4.7)	(4.5)	(9.9)	(0.6)	(5.9)	(1.45)		(3.5)
Income class									
G	−27.582	5.781	−0.326	−0.140	—	—	—	—	0.477
		(2.1)	(2.8)	(9.9)					(3.5)
1						−1.284	0.996		
						(3.4)	(1.8)		
2						−0.818	0.709		
						(2.0)	(1.2)		
3						−0.943	0.787		
						(3.4)	(1.5)		
4						−0.780	0.685		
						(4.0)	(1.3)		
Calories from rice, corn & fresh cassava									
Overall									
coefficient	−0.953	3.270	−0.169	−0.023	0.012	−0.514	—	−0.115	0.042
		(14.4)	(12.7)	(10.1)	(0.7)	(7.6)		(0.2)	(1.9)
Income class									
G	−8.598	2.852	−0.142	−0.098	0.013	—	—	—	0.028
		(7.0)	(6.3)	(3.0)	(0.7)				(1.3)
1	0.849					−0.329			
	(1.6)					(3.7)			
2	0.895					−0.849			
	(1.2)					(4.6)			
3	0.427					−0.711			
	(0.7)					(4.7)			
4	—					−0.579			
						(4.3)			

Note: All continuous variables are specified in logarithms. *UTX* is the *URBAN* dummy variable multiplied by *TX*, the log of per capita total expenditures. *PTX* is *TX* times *POOR*, a dummy variable equal to one for the lowest of twelve expenditure classes in the sample survey ($TX \leq$ Rp1000/month). *UPCAL* is *URBAN* times the logarithm of calorie prices. *PRICE* always refers to own price for the commodity in question and *XPRICE* refers to cross price (cassava prices in the rice regressions; rice prices in the cassava regressions). All regressions were estimated with *SPSS* regression programs using the *WEIGHT* procedure with the square root of cell size weights for each cell observation.

specific price effects (numbers 2, 4, and 6). Such directly estimated income-class-specific price effects have not been reported in the literature. But the income elasticities are also quite important because of the debate in the nutrition planning literature over the response of calorie-deficit populations to higher incomes. Table 2 shows that for both specific commodities and for calories from the three sources, the income elasticities for the Indonesian poor are quite substantial.

Rice income elasticities are extremely high for the first two income classes, indicating it is almost a luxury good for the bottom 30%–40% of the Indonesian population. Even high income populations increase their rice intake with higher incomes, especially in the rural areas. Regression 2 does not show a

	RND 2	W JAVA	C JAVA	E JAVA	SUMATRA	KALIMAN	SULAWESI		Regression Number	R^2
Rice										
Overall coefficient	−0.106 (3.0)	0.039 (1.1)	−0.059 (1.1)	−0.149 (2.4)	0.148 (3.0)	0.133 (2.3)	−0.370 (6.4)		1	0.69
Income class:										
G	−0.105 (3.0)	0.049 (0.9)	−0.068 (1.3)	−0.158 (2.6)	0.146 (3.0)	0.115 (2.0)	−0.361 (6.4)		2	0.71
1										
2										
3										
4										
Fresh cassava										
Overall coefficient	0.240 (1.7)	0.088 (0.4)	0.281 (1.3)	0.424 (1.7)	0.014 (0.1)	0.417 (1.8)	1.056 (4.7)		3	0.39
Income class										
G	0.232 (1.7)	0.072 (0.4)	0.285 (1.3)	0.420 (1.7)	0.010 (0.1)	0.414 (1.8)	1.038 (4.6)		4	0.39
1										
2										
3										
4										
Calories from rice, corn & fresh cassava								UPCAL		
Overall coefficient	0.002 (0.1)	−0.071 (2.1)	−0.180 (5.0)	−0.164 (4.1)	0.014 (0.5)	−0.015 (0.4)	−0.198 (5.5)	—	5	0.72
Income class										
G	0.018 (0.8)	−0.048 (1.4)	−0.156 (4.4)	−0.146 (3.7)	0.037 (1.2)	0.016 (0.4)	−0.178 (5.0)	−0.232 (1.4)	6	0.73
1										
2										
3										
4										

negative income elasticity of demand for rice in urban areas until per capita total expenditures reach Rp12,600 per month, and the figure is Rp16,300 per month in rural areas. Substitution away from rice with higher incomes is occurring for less than 5% of the Indonesian population.

Income elasticities for fresh cassava are also surprisingly high. They are near one for the bottom 10%–15% of the rural population and remain positive for 50%–60% of the population. Although the effective income elasticity of demand for cassava in the past decade has no doubt been negative due to the concentration of income growth among upper income groups, higher incomes among the bottom half of the population, and especially the rural population, would be likely to generate significant increases in demand for fresh cassava. Statistical results for *gaplek,* a form of dried cassava, are not available currently, but graphical analysis shows that virtually all *gaplek* is consumed by the bottom two income classes, and the income elasticity is probably negative even for these groups.

The calorie income elasticities tend to be somewhere between the rice and fresh cassava elasticities. The calorie regression was run on rice, maize, and fresh cassava calories, and it shows income elasticities of about 0.7 for the

Table 2. Income and Price Elasticities of Demand for Food in Indonesia

	Income Class				
	1 Low	2 Low–Mid	3 High–Mid	4 High	Average
Per capita total Expenditure (Rp/month)					
Value (*TX*)	1,548	2,513	3,876	9,085	5,412
Range	<2000	2000–3000	3000–5000	>5000	6151
Proportion of Indonesian population					
Susenas sample	0.106	0.185	0.321	0.388	
Population weight	0.154	0.237	0.324	0.285	
Income elasticities					
Rice: Urban	0.997	0.759	0.533	0.070	0.265
Rural	1.168	0.924	0.704	0.364	0.581
Fresh cassava: Urban	0.839	0.522	0.230	−0.369	−0.047
Rural	0.994	0.679	0.394	−0.046	0.410
Calories[a]: Urban	0.740	0.584	0.435	0.130	0.261
Rural	0.776	0.615	0.470	0.246	0.471
Price elasticities					
Rice	−1.921	−1.475	−1.156	−0.743	−1.105
Fresh cassava	1.284	−0.818	−0.943	−0.780	−0.804
Calories[a]: Urban	−0.561	−1.081	−0.943	−0.811	
Rural	−0.329	−0.849	−0.711	−0.579	−0.514
Cross price elasticities					
Rice with fresh cassava	ns	ns	ns	ns	
Fresh cassava with rice	0.996	0.709	0.787	0.685	0.765

[a] Calories from rice, shelled maize, and fresh cassava only.

bottom 10%–15% of the population, declining to about 0.2 for the upper quarter. Because these income elasticities are likely to be lower bounds to the actual elasticities because fish, meat, eggs, and milk calorie sources are not included, the conclusion must be that directing income to the poor will be a quite efficient way to improve their calorie intake.

Income-class-specific income elasticities of demand for various foods and for calories are standard in the nutrition planning literature if for no other reasons than the good fit of semi-log consumption functions. The same is not true of price elasticities, which are frequently hard to estimate for an entire population where data series are short and none too accurate, as is typical of data from many developing countries. Estimating price elasticities by income class simply has not been done with any confidence.

Consequently, the income-class-specific price elasticities reported in tables 1 and 2 are important just on methodological grounds. More important, however, is the boost they give to the a priori notion that the poor respond much more sensitively to price changes than do the rich. Although the Slutsky relationship argues that this is likely because the budget proportion and income elasticity for basic food staples vary systematically by income class, the more significant price substitution by the poor extends beyond the Engel component of the total Slutsky effect. At least for rice and cassava, the information in table 2 permits the calculation of pure substitution effects which also vary systematically by income class.

Both the income and (average) price elasticities reported in table 2 are substantially larger in absolute magnitude than most of the standard coefficients reported in the literature. It is important to realize, however, that these elasticities are not likely to be representative of short-run change parameters. Since they are estimated from cross-section data, the only appropriate interpretation is that these elasticities refer to long-run responses expected after several years of adjustment to new income or price levels. Although regional and temporal covariance analysis via dummy variables for important provinces and survey rounds mitigates this short-run/long-run dichotomy to a substantial extent (and reduces the own price response as well, some of which depends on regional and temporal price differences that are removed by covariance specification) it would be hazardous to use the parameters in table 2 for predictions of annual changes in commodity or calorie consumption

in the face of income or price changes. However, even if the immediate response is only half of the long-run response (implying an adjustment coefficient of 0.5 in a Nerlovian adjustment model, a figure in keeping with what little empirical evidence exists) the parameters in table 2, and especially the price parameters, remain dramatically large.

Are they surprisingly large? The question can be answered only relative to expectations. But in the multi-staple food economy of Indonesia with prevailing low levels of average caloric intake, such parameters would be quite consistent with an economically calculating population. Relatively wealthy populations can afford both strongly held food preferences and consumption patterns. The income elasticities for rice show that Indonesians do have strongly held food preferences and will exercise them as income permits. But the price elasticities reflect an ability to adjust consumption patterns in economically rational directions despite those preferences. At least among the bottom 30%–40% of the population income and price policies will meet with very sensitive and appropriate response.

Implications for Food Policy Analysis

Raising basic food prices as an incentive to farmers clearly has an adverse effect on food intake by consumers, especially those poor consumers already at substantial risk of consuming inadequate protein and calories. The results reported here argue that for this society "food" should be disaggregated into its important calorie sources. Doing so opens the possibility of providing farmers incentive prices for the preferred food (rice) and charging consumers relatively higher prices as well, while keeping the prices of secondary grains (maize) and root crops (cassava) low, even subsidized, to protect the poor.

A differential price policy targets the nutritional impact without the enforcement costs and leakages of programs using more preferred foods. The policy is self-enforcing because the poor eat staples no longer attractive to the higher income groups.[1] This avoids subsidizing the food consumption of the entire population, which tends to bankrupt a poor country. The strategy calls for high political commitment to increasing the access of the poor to adequate food supplies, but it may also be the only financially feasible way of coping with protein-calorie malnutrition over the next several decades.

As this paper indicates, the data and analytical costs of such a multi-commodity price policy are quite high. But these high analytical costs must be compared with the costs of subsidizing food consumption for much of the population or of attempting to enforce target-oriented food distributions that really reach the poor. The combination of high analytical and high political costs is not very attractive. But neither are the alternatives. Domestic resource constraints and international market realities will force the political costs of higher rice prices to be paid eventually. Paying the analytical costs now may prevent the political costs from being paid without any return in nutritional well-being for the poor.

Reference

Government of Indonesia, Central Bureau of Statistics. *SUSENAS*. Indonesian Socioeconomic Survey V. Jakarta, 1976.

[1] We recognize that fresh cassava is eaten in about equal per capita quantities by all income groups, but even this is a much more "equitable" consumption pattern than for rice. Maize seems to be in between rice and fresh cassava in this regard. Hence, subsidizing fresh cassava would involve about equal subsidies to all income groups whereas subsidizing rice subsidizes the rich more than the poor in per capita terms (perhaps not in percentage of income terms). Subsidizing *gaplek* would target the impact almost entirely on the poor unless diversions to livestock feeding became significant.

Target Group-Oriented Food Programs: Cost Effectiveness Comparisons

Marcelo Selowsky

Food programs oriented to specified income or age groups are being implemented at different scales by several developing countries. Others are actively experimenting with them at the level of pilot interventions. International aid institutions have become interested in them for financing. The case for target-oriented programs has become increasingly clear as a result of several factors.

First, there is the recognition that the normal course of development will not close with sufficient speed the caloric deficits observed today in the poorest subgroups of the population of these countries. Young children, overrepresented in the total malnourished population, could suffer further from declines in breast-feeding practices and lower shares of food resulting from increased urbanization. Second, general programs that lower the price of food to all consumers are either too expensive from a fiscal point of view (general production and consumption subsidies) or, if governments want to save in fiscal costs, they entail a disincentive to domestic producers (price controls, procurement policies). Finally, the fact that malnutrition results from an unequal distribution of food consumption—rather than a lack of aggregate supply—calls for programs that redistribute food within the population instead of general subsidies encouraging aggregate consumption.

In an earlier work (Reutlinger and Selowsky) comparisons were made between the effects of target and general programs, the objective being an expansion of food consumption in families with caloric deficit. Target-oriented programs were defined as those that only subsidize or deliver concessionary food to these target families. General programs were those that subsidize all types of consumers. Cost effectiveness was defined in terms of the fiscal cost of achieving this extra consumption in these families, irrespective of how this extra consumption is being distributed between adults and children.

Here we want to evaluate programs in terms of their effectiveness in increasing food and calorie consumption in the children of these families. Children have become a distinctive objective as countries increasingly recognize the adverse effects of children's malnutrition. Where present general food programs must be scaled down or are not feasible due to fiscal constraints, sharply targeted approaches to nutrition interventions must be identified. This paper presents, first, a simple taxonomy of target-oriented food programs that leave unchanged the marginal rate of substitution among foods. Their cost effectiveness is compared relatively to an equivalent income transfer (i.e., equal to having received the subsidy in cash). It then addresses programs that induce substitution among foods and its probable effect on calorie consumption. Finally, it discusses the implications of moving from a (fiscal) cost effectiveness analysis of programs to a benefit-(resource) cost evaluation.

Cost Effectiveness Comparisons

Three programs are compared: a ration shop scheme where preselected families received subsidized rations of food, a subsidized food stamp program for the families, and a free on-site feeding program for children in those households. When these programs are inframarginal to previous levels of consumption, they all become equivalent to an income transfer. This holds when the quantity of food or stamps distributed is smaller than the amount previously consumed by the family, or by the child in the case of the feeding program. This is true even when ration shops or site-feeding programs distribute several foods in different proportions to the ones previously consumed.

Marcelo Selowsky is economic adviser in the Development Economics Department of the World Bank.

The views presented here are those of the author and do not necessarily represent those of the World Bank.

As long as all foods are inframarginal to previous levels of consumption, the marginal rate of substitution will remain unchanged, the condition for a program to operate like an income transfer. We believe inframarginality characterizes most programs being implemented today.

If programs provide subsidized food, on-site feeding or food stamps in excess of initial consumption (noninframarginal programs), households will try to make use of the possibility of resale so as to increase their set of consumption choices.[1] Food eaten on site cannot be resold, so for this program the option is not open. However, part of the concessionary food received in ration shops as well as a fraction of the food stamps can be resold. Consequently, the effectiveness of these programs becomes equal to an income transfer. Assume, however, the food or stamps, due to heavy policing or high transaction costs, are not resold. What is then the cost effectiveness of these programs? Is that effectiveness still equal to an equivalent income transfer? How do these three different programs now compare in terms of the additional food consumed by children?

Cost effectiveness will be defined as the fiscal cost of increasing by one dollar the aggregate food consumption of children (not the per capita consumption by each child). The comparisons do not distinguish or capture the distribution of that additional dollar among children. A second consideration is that the effectiveness of an income transfer relative to the other programs is quite sensitive to the precise definition of "children." The effectiveness of an income transfer is proportional to the marginal propensity to spend in children's food (i.e., the increase in the aggregate value of food consumption of that group of children). If the group is defined rather widely (i.e., those below age 15) the relevant marginal propensity is much larger and income transfers become more effective. The reason is obvious: a smaller fraction of individuals is now considered as a nontarget age group, diminishing the "leakage" of the program. It is always possible to define children narrowly enough (i.e., those below age five) so as to make income transfers extremely inefficient: the additional consumption of older children also becomes a leakage.

In order to capture explicitly this last effect, we will define the marginal propensity to spend on children's food as γm_T, where γ is the fraction of individuals defined as "children," and m_T is the marginal propensity to spend on food consumption for households as a whole. This proportionality assumption is a simplification insofar as it assumes that the individual marginal propensity is the same for children as adults.[2]

Table 1 shows expressions for the cost effectiveness of the three programs. When the programs are inframarginal, all have the same cost effectiveness and are equal to an equivalent income transfer. In this case, the cost is inversely proportional to the marginal propensity to spend on children's food consumption, γm_T.

If the programs are "large enough" and resale is possible, the only program different from an equivalent income transfer is a site-feeding program for children. For the program to operate differently than an equivalent income transfer, the required scale of the program (the food given on site to all the children of the household) must be at least $1/1 - \gamma m_T$ times the food previously received at home. Under this type of program, the net increase in children's consumption—even if families stop feeding children at home—will be equal to the excess of the food given on site over the food previously eaten at home. Therefore, the cost effectiveness formula $\frac{1 + \lambda}{\lambda}$ is relevant for all programs where λ, the fraction by which one wishes children's consumption to increase, is larger than $\gamma m_T/1 - \gamma m_T$. For any objective λ below this value, the effectiveness of the program will be equivalent to an income transfer.[3]

---

[1] In fact, resale will start when the value of the food transfer is $\frac{1}{1 - M}$ times the food initially consumed, where M is the marginal propensity to spend in food.

[2] We can predict the bias of the assumption if adults have a larger individual marginal propensity than children—and we do have some evidence on it—the earlier assumption will overestimate the marginal propensity to spend in children; i.e., our estimates of the effectiveness of income transfer also will be overestimated. This will be important in interpreting the results.

[3] Let us explore the effectiveness of a site-feeding program under $\gamma m_T = 0.15$. In this case, any program whose objective is to increase children's consumption by more than 17.6% $\left(0.176 = \frac{0.15}{0.85}\right)$ can only do so by feeding children the full amount previously eaten at home plus an additional amount of food equal to the objective. If the program wishes to increase consumption by 20%, it has to feed children an amount 1.2 times the amount previously eaten at home. Thus, programs whose objective, λ, is larger than

Table 1. Cost Effectiveness Comparisons: Cost of Increasing by One Dollar the Value of Children's Aggregate Food Consumption

Type of Program	Inframarginal Programs	Programs in Excess of Initial Consumption	
		Under resale	Under No Resale
A subsidized food program for the household	$\frac{1}{\gamma m_T}$	$\frac{1}{\gamma m_T}$	$\frac{1+\lambda}{\gamma m_T + \beta\eta^s}$ [a]
A food stamp program for the household	$\frac{1}{\gamma m_T}$	$\frac{1}{\gamma m_T}$	$\frac{1}{\gamma}\left[1+\left(\frac{1-f}{\lambda}\right)\right]$ [b]
Direct on-site feeding of all children	$\frac{1}{\gamma m_T}$	$\frac{1+\lambda}{\lambda}$ (full feeding)	$\frac{1+\lambda}{\lambda}$ [c] (full feeding)
An income transfer to the household		$\frac{1}{\gamma m_T}$	

Note: γ is children as a fraction of family size; m_T, marginal propensity to spend in household's food consumption; λ, desired increase in children's food consumption as a fraction of the initial consumption; η^s, "pure substitution" price elasticity of children's demand for food; β, share of food consumed by children; f, price charged for the food stamps, expressed as a fraction of the initial amount of food consumed by the family.

[a] Assumes that the total price elasticity of demand is equal for children and adults.

[b] Holds for $f > 1 - \lambda\left(\frac{1-m_T}{m_T}\right)$.

[c] $\lambda > \frac{\gamma m_T}{1-\gamma m_T}$; condition for "full feeding."

It can be shown that an increase in a household's food consumption by a fraction λ can be achieved by providing the family with stamps equal to $(1 + \lambda)$ times their previous consumption and charging a price for the stamps that ranges between $1 - \lambda(1 - m_T)/m_T$ and one times the value of the food initially consumed. The higher the price charged—within the above range—the higher the effectiveness of the program (i.e., the cheaper the program). If either the price charged for this amount of stamps is below $1 - \lambda(1 - m_T)/m_T$ or the implicit subsidy of charging this price is maintained and less stamps are distributed, the program will be equal in its effectiveness to an equivalent income transfer. The expression in table 1 can be broken down into two components: $1 + (1 - f)/\lambda$ is the cost of inducing one extra dollar of food consumption in the household; γ is the fraction of that extra dollar that will be consumed by children.

The subsidized food price program defined here is different from the typical ration shop scheme where the family does not have the freedom of buying as much as it wishes at the subsidized price. In the ration shop scheme, the family receives an inframarginal ration which, as discussed earlier, is equivalent to an income transfer. Here the family has the freedom to purchase at the subsidized price as much as it wishes; however, given that resale is not possible it will only purchase the amount demanded for own consumption, the quantity purchased will be on the demand schedule of the household. The cost effectiveness expression for this program includes two new parameters other than λ and γm_T. One is η^s, the (pure substitution) price elasticity of food demand of children, capturing the substitution in favor of food that takes place when the subsidy changes the relative price between food and nonfood. The program has changed the marginal rate of substitution between food and nonfood, an effect that was not present in programs equivalent to an income transfer. The larger the value of η^s, the more cost effective will be the program. The parameter β corrects for the additional leakage—being financed by

$\gamma m_T/1 - \gamma m_T$, can only be implemented by what might be called a "full feeding" program, i.e., the program must be able to compensate for the possibility of a 100% replacement at home.

the subsidy—that takes place when part of the additional food demanded by the family is consumed by adults.

Table 2 presents the cost of the program in terms of the cost effectiveness of an equivalent income transfer (i.e., the numeraire). Table 3 presents results under alternative values of the parameters.

A value of m_T—the households' marginal propensity to spend in food—equal to 0.5 is used throughout the analysis. We believe this figure to be an upper limit.[4] Thus, the effectiveness of an income transfer is being overestimated. It means the relative cost figures for the other programs shown in table 3 represent maximum values. The two assumed values of γ, equal to 0.2 and 0.33, can be interpreted as two alternative definitions of "children." A value of 0.2 corresponds to children below age five, and a value of 0.33 to children below age ten. Under the broader definition of children, the income transfer clearly becomes more effective due to a smaller leakage. The relative cost of the price subsidy and site-feeding programs increases. The relative cost of the food stamp program remains the same since the food leakage resulting from redefining children affects proportionally the effectiveness of both programs.

[4] Only for the poorest one-third of households in Calcutta we have found values of this magnitude. For most poor income groups in urban Latin America, the value of m_T fluctuates between 0.3 and 0.4. See C. Lluch et al.

As expected, a very narrow definition of children makes all programs more cost effective than an income transfer. The exception is "low" priced food stamp programs; f must be larger than 0.75 for these programs to be better than an income transfer. For objectives equal to $\lambda = 0.3$, stamps programs with a high price, and on-site feeding programs become the best interventions. This is also true under a wider definition of children, which only induces a difference in ranking between "high" priced stamps programs and on-site feeding: stamp programs become now more effective than site feeding.

For policy purposes the above figures must be adjusted by two factors: first, the difference in administrative costs of the different programs. Countries who already have an infrastructure of health centers, rural schools, etc., require less additional (nonfood) resources to carry out on-site feeding programs. Second, the assumption of no resale is perhaps less realistic for some programs than for others (i.e., subsidized food price programs relative to food stamp programs). If resale is always possible the only intervention that can be more cost effective than an income transfer is an on-site "full feeding" program.

Substitution

The programs discussed earlier did not induce a change in the composition of food consumption. Therefore, the percentage change in

Table 2. Cost Effectiveness Comparisons: Relative Cost of Increasing by One Dollar the Value of Children's Aggregate Food Consumption, Cost Relative to an Income Transfer Program (all figures of table 1 are divided by $[1/\gamma m_T]$)

Type of Program	Inframarginal Programs	Programs in Excess of Initial Consumption No Resale
A subsidized food program	1	$\dfrac{1+\lambda}{1+\dfrac{\beta\eta^s}{\gamma m_T}}$
A food stamp program	1	$m_T\left[1+\dfrac{(1-f)}{\lambda}\right]$ [a]
Direct on-site feeding of all children	1	$\gamma m_T\left(\dfrac{1+\lambda}{\lambda}\right)$ [b]

[a] Holds for $f > 1 - \lambda\left(\dfrac{1-m_T}{m_T}\right)$.

[b] Holds for $\lambda > \dfrac{\gamma m_T}{1-\gamma m_T}$; condition for "full feeding."

Table 3. Cost Effectiveness Comparisons in Terms of the Cost of an Income Transfer Program (m_T = 0.5)

Type of Program	Inframarginal Programs	f	Programs in Excess of Initial Consumption; No Resale: $\gamma = 0.2$, $\lambda = 0.15$	$\gamma = 0.2$, $\lambda = 0.30$	$\gamma = 0.33$, $\lambda = 0.15$	$\gamma = 0.33$, $\lambda = 0.30$
A subsidized food program	1		0.76	0.87	0.88	0.99
A food stamp program[a]	1	f = 0.25	1	1	1	1
		f = 0.50	1	1	1	1
		f = 0.75	1	0.92	1	0.92
		f = 0.9	0.83	0.66	0.83	0.66
		f = 1.0	0.50	0.50	0.50	0.50
Direct site feeding of all children[b]	1		0.77 (full feeding)	0.43 (full feeding)	1	0.71 (full feeding)

Note: The other parameter values are: $\eta' = 0.5$; $\beta = 0.1$.
[a] The conditions for the program to operate like an income transfer are: For $\lambda = 0.15$, $f < 0.85$; for $\lambda = 0.30$, $f < 0.70$.
[b] The conditions for the program to operate like an income transfer are: For $\gamma = 0.2$, $\lambda < 0.11$; for $\gamma = 0.33$, $\lambda < 0.197$.

calorie consumption was equal to the one in food consumption. For noninframarginal programs and no resale the earlier analysis assumed that either one food provided most calories (i.e., cereals)—where all programs were designed in terms of that food, or in the case of several foods, that the program left unchanged the marginal rate of substitution among foods. For the price subsidy program, this assumes all foods are subsidized by the same percentage. For the site-feeding program, it assumes the composition of foods given on site to be equal to the composition of foods previously eaten at home.

What happens if programs do change the composition of food consumption? How do we then predict the change in calorie consumption? When substitution takes place, the increment in the consumption of a particular food (that is being subsidized or provided by the program) can induce a decline in the consumption of foods that are substitutes. If that substitution is strong and the foods being substituted account for an important share of the initial calorie consumption, the net effect on calorie intake could be negative. In order to predict these changes, cross-price elasticities of children's food consumption are needed. This information is extremely scanty even at the level of aggregate household consumption.[5] For children it is absent. Thus, we can only speculate about the effectiveness of particular programs when these substitutions are present. It will become clear that many of the present nutrition interventions fall into this category.

Milk price subsidies or free distribution (take home programs) of milk in amounts substantially above the previous consumption of the household are typical cases. If resale is not possible, these policies will induce a substitution among food commodities. Let us assume children consume two basic foods, cereals and milk. The effect of those programs will be to increase children's consumption of milk and to increase or decrease children's consumption of cereals, depending if milk and cereals are complements or substitutes, respectively.[6]

If milk and cereals are substitutes (the decline in milk's implicit price decreases children's cereal consumption), total calorie consumption could decline if, as is usually the case, most of the calories are derived from cereals. It can be shown that, in this case, even a small degree of substitution between the two foods could induce a negative effect on caloric intake.

The percentage change in calorie consumption induced by a one percent decline in the price of milk, K_M, can be written as:

$$K_M = \alpha_M \eta_{MM} + \alpha_C \eta_{CM}, \tag{1}$$

[5] For an interesting use of these elasticities in predicting the caloric effect of changes in the supply of particular foods, see Pinstrup-Andersen et al.

[6] We define substitution including the corresponding income effect, i.e., gross substitution.

where α_M and α_C are the initial shares of calories derived from milk (M) and cereals (C), respectively; η_{MM} is the (own) price elasticity of demand of milk and η_{CM} the (gross) cross elasticity between cereals and milk; η_{CM} is assumed positive, both foods are (gross) substitutes. In order for K_M to be positive, i.e., for the subsidy on milk to have a negative effect on calorie consumption, we need the condition:

$$\frac{\alpha_M}{\alpha_C} < \frac{\eta_{CM}}{\eta_{MM}}. \tag{2}$$

If $\alpha_M/\alpha_C = 1/5$, initially four-fifths of the calorie intake came from cereals, any cross elasticity larger than one-fifth the value of the own price elasticity for milk will induce a negative effect on calories. If the price elasticity of milk is one, any (positive) cross elasticity larger than 0.20 will have this effect. Milk subsidies and free distribution of milk programs are popular programs in the present. Perhaps they were basically conceived with the objective of increasing the consumption of "high quality" proteins. However, if calories are the major nutritional problem, a reevaluation of milk programs along the lines described earlier becomes of prime importance.

The problem of predicting this substitution becomes even more difficult when a program introduces a food previously not being consumed by children. In this case, the notion of an inframarginal or noninframarginal program loses its meaning: any amount of the food being distributed could affect negatively the consumption of calories. When a program distributes an inframarginal amount of a food previously being consumed, the released purchasing power is used to expand the consumption of all food commodities, by both adults and children.[7] If the new food being introduced by the program can only be consumed by children (specific baby foods), or is fed directly to children (milk programs in schools when children were not previously consuming milk), the only mechanism by which the rest of the family can also benefit from the transfer is by withdrawing some other food from the children in question.[8] As long as the rate of substitution between foods, as seen by the household, does not fully internalize the different calorie intensity of foods, the resulting substitution could adversely affect the calorie consumption of children.

From (Fiscal) Cost Effectiveness to (Resource) Cost-Benefit Analysis

The cost effectiveness formulation presented earlier is clearly incomplete from the point of view of a full welfare economics analysis. First, it includes as costs all fiscal outlays, regardless of what fraction of them represent a resource cost or simply a transfer. It becomes more relevant when the fiscal budget is the ultimate constraint to the selection of programs. Second, the benefits are expressed in terms of physical quantities without prices being attached to it. Implicitly each extra unit of consumption has the same value to society. Third, a zero value is given to the extra consumption in the nontarget groups when they also become subsidized.

A more comprehensive welfare analysis could be undertaken if a "social" demand—different from the market demand—is used to value the extra consumption in the target group. As suggested by Harberger this will be the case if the extra consumption of particular commodities (i.e., calories) by particular subgroups of the population is considered as an externality or public good to the rest of society. In these circumstances we can determine the subsidy or scale that maximizes the welfare gain of each program and then choose among programs according to the magnitude of this welfare gain. Let us illustrate this graphically.

Assume additional food consumption by the children of poor families represents this externality, generating a social demand (D^*) that is higher than the market demand (D_p). The pro-

---

[7] We assume all foods are superior at low levels of income.

[8] Assume a utility function of the household equal to: $U = F^{\alpha} R_a^{1-\alpha}$, where R_a is rice (or an index of cereals) consumed by adults and F is an index of the food consumed by children. Suppose F is a CES index of milk (M) and cereal intake (R_d) consumed by children.

$$F = [\delta M^{\rho} + (1 - \delta) R_d^{\rho}]^{\frac{1}{\rho}} \qquad \rho = \frac{\sigma - 1}{\sigma},$$

where σ is the elasticity of substitution. If initially the child did not consume milk, first order conditions yield an allocation of cereals, A_o, equal to $A_o = \frac{R_d}{R_a} = \left(\frac{\alpha}{1-\alpha}\right)$. When the child is fed at school an amount M_o, the first order condition yields a new allocation of rice equal to $A_1 = \dfrac{A_0}{\left(\frac{\delta}{1-\delta}\right)\left(\frac{M_o}{R_d}\right)^{\rho} + 1}$. Clearly $A_1 < A_o$, the relative allocation of rice to children declines. Because expenditure in rice (cereals) is always equal to total income, this decline involves a decline in the absolute amount of rice consumed by children.

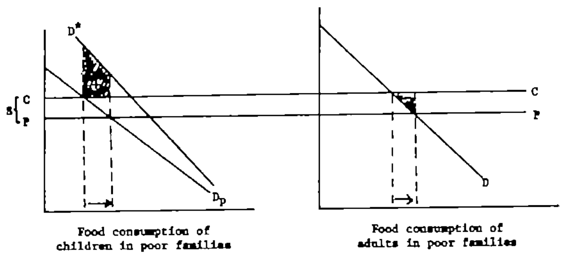


Figure 1. Food consumption in poor families

gram under consideration is a price subsidy (s) to these families (resale is not possible) to bring down its price below its resource cost C

tion there exists an "optimal leakage," the one associated with the subsidy s^*.

From a theoretical point of view, this type of welfare analysis is clearly an improvement over the (fiscal) cost effectiveness approach presented earlier. Several issues must, however, be resolved to make the analysis operational. First, how do we derive the value of ϕ. Second, a penalty must be imposed on that part of the fiscal funds that end up as pure transfers. The (fiscal) cost effectiveness approach treats one dollar of transfers as one dollar of real cost. In the welfare analysis pure

Some Issues in Transportation Policy: Problems in Preference Articulation

James D. Shaffer

In this paper I deal mostly with questions, not answers. The questions have implications for policy analysis. I am concerned with political-economic problems of improving the performance of the U.S. transportation system. Attention is focused on problems of instituting market and political mechanisms for articulating preferences for transportation. Because of public goods characteristics and pervasive externalities of transportation, the blending of market and political processes is especially difficult and important. By preference articulation, I mean the processes by which participants in the political economy get their preferences taken into account. Preference articulation has two aspects: the mechanisms for identifying preferences and the responsiveness of the system to preferences.

I have organized discussion of issues under five general headings—pricing and regulations, jurisidictional boundaries, energy, settlement patterns, ownership, and some observations on difficulties encountered in implementing a public program in rail service continuation. All the issues are interrelated.

The discussion of issues suggests the need for comprehensive long-run planning, while the observations of political practice illustrate the difficulty of political decision making even for a small program.

The Transportation Meta Plan

Consider the attempt to develop transportation meta plans at the national, state, and local levels. By a meta plan I mean a plan for making plans and policy decisions. The objective would be to provide a process for systematic evaluation of our long-run transportation "needs" and alternative approaches to transportation policy given the probable constraints of the future. We cannot know with certainty either the future demands for transportation or the constraints, but current decisions must be made based upon the best estimates available. The process of debating a meta plan should provide a framework for more informed political preference articulation with respect to desired performance and major alternative developments in the transportation system. The meta plan should provide useful guidelines as a framework for making specific planning, funding, and regulatory decisions affecting transportation. The current Rural Transportation Task Force may provide elements of such a plan.

We are spending more than 20% of the gross national product (GNP) for transportation. Performance of transportation affects all aspects of the economy, and disruption threatens the social order. We face critical issues in transportation which should be identified and debated, not only in the Congress but also in the political parties, state legislatures, within and among interest groups, and among economists and other policy analysts.

Pricing and Regulations

The concept of an unregulated market is a meaningless construct. Markets always reflect both preferences for specific products and political preferences reflected in regulations, rights, taxes, and subsidies. Thus, all prices are political and a particular equilibrium price has no unique economic significance as an indication of preferences or value. Broadly conceived, price is an instrument of regulation. It is an inexpensive means of rationing. It is also an effective instrument for reflecting prefer-

---

James D. Shaffer is a professor of agricultural economics, Michigan State University.

Michigan Experiment Station Paper No. 9101.

The author acknowledges comments by H. Riley, S. Thompson, T. Pierson, J. Tucker, L. Hamm, B. Ferres, C. Cordes, and J. Schmelzer.

ences of large numbers of people once the pattern of political constraints is established.

Decisions in regard to regulation and government participation in transportation must be pragmatic. The market price system, where buyers have strong incentives to weigh alternatives before purchasing and sellers have incentives to identify consumer demand and search the opportunity set for low-cost means of responding to demand, is a marvelous mechanism for preference articulation where the appropriate benefits and costs are taken into consideration. The political process produces regulations, taxes, subsidies, and government provision of services in an effort to achieve performance which is preferred to what would have resulted without the government action. The problem is that the political process is not a very effective mechanism for citizen preference articulation. It is difficult to express efficiently preferences in the political process and there are problems in designing bureaucracies to be responsive to preferences.

The problem of pricing transportation is particularly difficult because of the nature of the economies of density—the marginal cost of a unit of production is usually very low relative to average total costs—and physical characteristics which limit competition. Thus, rate regulation, government provided service, and politically determined user charges are critical issues.

User Charges

User charges reflecting full costs would test users' preferences and could create an incentive to use the least-cost method. But how should costs be allocated among types of users? This is a critical issue for trucks and cars in determining highway user charges. Full cost pricing would not necessarily result in the lowest system cost in supplying transportation.

A current issue is the failure to maintain and modernize rural roads and bridges. It is a serious problem, but I have not seen good benefit/cost analysis dealing with the investment. Baumel suggests part of the problem arises because of the use of much larger farm equipment and trucks. Would it be more efficient to use smaller equipment than to build larger bridges? If users of large equipment had to pay the extra cost of the roads and bridges, they might choose different equipment. Transportation must be analyzed as a factor of production in a complex system.

Cross-Subsidies

If regulation requires a firm to provide some customers service at a price below costs, resulting in higher prices to others, this is the same as a tax and subsidy. Would the political process weigh costs and benefits more accurately if direct subsidies were used and the costs appeared explicitly in a budget?

Transportation pricing involves extensive cross-subsidies with or without rate regulation. Rates vary from commodity to commodity and from place to place and are not closely related to costs. This raises significant questions of equity. A special problem involves the granting of low rates to large shippers because of the potential effect this has on industrial structure. Has the substantial differential in rates on unit train shipments of grain led to concentration in the grain trade? Or, will it do so? What is the appropriate theory of allocation of overhead costs for multiproduct firms to provide effective guidance for establishing rates leading to desired performance?

Captive Shipper

The problem of the captive rail shipper is especially critical. Where there is not effective competition, some control must be placed on rates. But what are the appropriate decision rules for establishing and enforcing rates? There does not appear to me to be any basis for the belief that two-firm competition among railroads would reduce the need for rate regulation.

Rail Car Shortage

Perhaps the most common complaint about rail transportation by shippers is the shortage of rail cars. To an economist it appears to be a problem of peak load pricing. It simply is not profitable to supply cars to meet peak demands given current price practices. Here the market should work to allocate cars to shippers with greatest demand. J.O. Gerald suggests separate pricing of the car and the hauling service to get a more effective articulation of demand for cars. With appropriate pricing mechanisms, investors would have an incentive to supply more cars if needed. The cost of leaving cars idle or using them for storage

would be increased, thus increasing the supply of cars, and leading to more efficient decisions between shipping and storage. At least there would be no car shortage. What would be the consequences and problems I do not anticipate?

These are only a few of the complex problems involved in pricing and regulation of transportation.

Jurisdictional Boundaries

A general issue in transportation policy involves determining appropriate jurisdictional boundaries.

Geographic Boundaries

Every unit of government from the township and village to the federal government is involved with transportation. As a general rule, better resource allocation would be expected where costs and benefits were closely associated within the same unit. The costs and benefits of a decision by one unit which accrue to other units often are not taken into account by the decision-making unit. The problem of devising appropriate boundaries and related funding and regulation decision rules is complicated by the pervasive effects of transportation and the problems of collecting revenue in relationship to benefits. The classification of roadways and related formula funding by the federal and state governments is a response to this problem.

The Railroad Reorganization Acts provided federal subsidies for rail service continuation on light density lines. At least one state tended to make decisions on the basis of the state's share of the cost, not the total costs. A different evaluation would be made if local governments and users were required to contribute to the funds for rail service continuation.

A benefit frequently included in analyses of rail service continuation projects is its effect on employment and income. These estimates are clearly related to the boundary of the area under consideration. Discontinuation of rail service may affect employment and income in the immediate area, but would have little if any effect for the total nation.

The federal government has an advantage as a tax collector. For example, state and local taxes on gasoline result in purchases in lower tax areas. State taxes may affect location decisions, and tax competition among states is common. Economies may exist for both collecting and paying taxes. Thus, federal taxation and funding of transportation is appropriate, but what decision rules for distribution would contribute to desired performance?

The recent truckers' disruption of service was due in part to inconsistent regulations among states. The variations in regulations would be justified if they reflected real differences in circumstances or preferences. In this case, the federal government has a role in establishing regulatory standards. Perhaps federal regulation should prevail on highways built with a specified percentage of federal funds.

Agency Boundaries

The jurisdictional boundaries among agencies is another important issue. The problem is to design agency responsibilities in such a way that benefits and costs are compared among alternative actions. Are multimodal departments of transportation more likely to take into consideration the extensive interdependence among transportation modes than the single mode agencies? Interdependencies of transportation policy with other areas of policy are pervasive. Rural areas and farming interests, for example, are likely to be better served if the U.S. Department of Agriculture (USDA) and state departments of agriculture participate in government transportation decisions. The same is true of most other agencies.

Adjusting to the Energy Situation

Energy and transportation policy are closely linked. Estimates are that more than 40% of the energy marketed in the United States is used for transportation. The current transportation system is designed to use oil-based fuels. Oil reserves are being depleted at a rapid rate. My colleague, Herman Koenig, has calculated that oil production has doubled about every ten years since 1890; and if this rate were to continue, the most optimistic assessments of remaining world recoverable crude oil (169×10^9 barrels) and oil from shale (760×10^9 barrels) would be depleted in only thirty-four years. The real cost of oil will increase substantially and we will run out of oil that is economically available for transportation in a relatively short period of time unless

significant conservation occurs. Other sources adaptable to transportation needs are uncertain and probably will be expensive.

Market Problem

The price system alone is not an adequate means of articulating preferences in this situation. The market does not provide a mechanism to express adequately the demand for the option to buy in the future. Nor does the market adequately reflect preferences for conservation because of the free rider problem? That is, if I conserve and others do not, my conservation because of the free rider problem. That future. The use of oil by one person imposes costs upon others. Dependence on foreign oil has substantial and critical implications for defense, international relations, and monetary stability which cannot be reflected in the market. What is the appropriate policy to deal with the allocation of a critical nonrenewable resource over time?

What policies are appropriate to make transportation more efficient in the use of energy resources and to reflect effectively preferences for conservation? Modes of transportation differ greatly in energy use related to lengths of haul and size of load. Water and rail are much more efficient for long hauls and large loads than trucks. Trucks are more fuel efficient for short trips and small loads. Thus, an energy efficient transport system will be one with efficient intermodal connections. What role should the government take in facilitating development of cost-effective multimodal systems? Individual carriers cannot make effective systems changes.

Railroads

An energy efficient, integrated, multimodal transport system requires efficient railroads. Many diagnoses of the rail system have been made and the conclusions are that many factors have contributed to their poor performance. Because of economies of density, the loss of one shipper reduces the ability of the railroad to serve others, and a process of sequential quality deterioration sets in. Large volumes of commodities are shipped by truck for long distances, commodities which could be shipped by rail at considerable saving of fuel. Shippers chose trucks for long shipments because of differences in quality of service relative to direct transportation costs. Some rail subsidy may be necessary to obtain the benefits to be derived from energy savings. An alternative to the subsidy would be to require certain classes of shipment to go by rail. This would create private costs, equivalent to a tax, but would be largely beyond observation by those ultimately paying.

Conservation Practices

There are many public and private practices in transportation that waste energy. Examples include: the scheduling of aircraft take-off and landings results in large energy losses while planes circle and wait in line; the subsidy or nonpricing of parking by employers and cities which reduces the incentive to car pool and to use public transit; the organization and revenue splits of railroads, which results in longer-than-necessary routing; and extra miles traveled due to competition on delivery and assembly routes which could be served by a common carrier. There must be hundreds of examples. Higher fuel prices will modify some of these practices, but others will not be altered by prices—political action will be required. Responding to the truckers' demands for lower diesel fuel prices would, of course, have a perverse effect on efficient use of energy.

Regulating Use of Oil

A major issue of significance in oil conservation is the type of energy used for different purposes. In the production of electric power, close substitutes to oil exist. Space heating and rail transport could be converted from oil to processed pelletized coal or coal-based electric. Large-scale changes in energy sources would require complex systems changes and huge investments. Also, coal involves major environmental problems. Again, prices have a significant role to play in selecting uses consistent with preferences, but political decisions must also be made. The tradeoff decision between oil savings, current trucking services, personal mobility, and environmental quality are extremely difficult. My judgment is that adjustments to the evolving energy situation involve the most critical and difficult policy issues in transportation.

Settlement Patterns

Settlement patterns, transportation, and energy are intimately linked. Individual decisions in regard to location of activity are not likely to result in aggregate settlement patterns consistent with the preferences of those making the individual decisions because important benefits and costs are external to the individual decisions. For example, efficient public transportation requires a certain density of population. We generally have a dispersed population that makes public transportation uneconomical, and thus, the great bulk of the population is dependent upon the automobile. We have a dispersed population because roadways respond to demand generated by individual location decisions. Can policies be developed to achieve patterns of settlement which would reduce costs of assembly and distribution, costs of heating, and enhance the quality of the environment and life?

Early in our history public investment in railroads, waterways, and roads were made to stimulate economic development of the country. The public investment in rural farm-to-market roads influenced the location of agricultural enterprise. The interstate highway system was a huge investment which has had a great impact on location of economic activity. The reduced cost and improved service available by truck attracted business from rail and, because of density economies on rail lines, made some lines unprofitable. This left some businesses and communities without rail service. Lower cost truck service reduced assembly and distribution costs and made larger-sized food-processing plants more economical, thus eliminating many firms, which in turn reduced the viability of some small communities. Few of these consequences seemed to be taken into account in the planning of the interstate system.

High quality agricultural land is lost every year to alternative uses. Should transportation decisions consider the benefits of preserving this land, not just in terms of the land used for roadways, but for the settlement patterns which result because of the roadways?

Rail and truck regulations include a settlement pattern objective in the public service obligation. Analysts cannot put a value on service to rural areas which preserves small towns, but can provide information about costs and cost effectiveness.

People who are old, handicapped, or poor and who have no access to public transportation are at a serious disadvantage in participating in our automobile-oriented society. Access to many welfare services requires mobility. People in rural areas are generally without public transportation. Should the existing economic incentives be allowed to force this group to live in cities? My observation is that government actions have, on balance, contributed more to the problem than to the solution. For example, where Amtrak provides highly subsidized passenger service in competition with intercity buses, the bus services suffer. Similarly, publicly provided dial-a-ride services may destroy the economic viability of a taxi service. Regulations restricting entry to the passenger transportation business are probably the most important barrier to effective service. Could the market work with "private" vehicles providing the needed service inexpensively, as has been proven in many areas of the world?

My main points are that transportation policy should be in the context of explicit settlement-pattern objectives and that the market is important as a mechanism for articulating some preferences related to settlement patterns and not others.

Ownership

There are many issues of ownership and property rights related to transportation. The most critical issue currently involves the railroads. Much of the rail system is bankrupt or on the verge of bankruptcy. ConRail does not appear to have improved on the performance of the bankrupt railroads it replaced, even with large treasury costs. Prior to establishing ConRail, a proposal was made for government ownership of the railway, with private companies operating on the government-owned and maintained rails. The concept was known as ConFac. What would be the expected performance compared with ConRail-type solutions or long-term subsidies? By separating ownership of functions and reducing entry barriers would competition responsive to shippers' needs be stimulated? Could rate regulation then be eliminated or greatly modified? Restrictions on companies operating both rail and truck services could be eliminated. Would multimodal firms develop improved systems?

If budget decisions for development and maintaining ways, whether road, water, or

rail, were in the same governmental units, would this encourage better consideration of benefits and costs for expenditures in all modes as a system? System interfaces involving signaling and overpasses could be dealt with more rationally than in the current practice where railroads are generally responsible for maintenance of grade crossings and signals. User charges could be established to foster national objectives, including, first of all, effective performance at low cost, but also those relating to settlement patterns, energy conservation, and equity.

There would be many practical problems in changing to a ConFac rail system. Many institutional design decisions would determine the outcome. Traffic control would be a problem. Railroads, however, have operated with joint trackage rights for years; this would be an extension of that concept. The organization of labor would be a difficult problem, also. The political process would probably overinvest in the provision of ways; eliminating lines would be politically difficult.

Pipelines

The proposed construction of coal slurry pipelines is another significant issue involving the role of government and markets in preference articulation. Peterson has provided an interesting discussion of the pros and cons. The immediate issue is, should the government use the power of eminent domain to require the granting of easements for the right of way of coal slurry pipelines? This involves the taking of private property for use by a private firm. The market test for the decision for building such pipelines is expected profitability. There are, however, many benefits and costs external to the firm. Water would have to be obtained in the area of origination and dirty water disposed of at the other end. Both have environmental effects. Elimination of coal revenue to railroads could seriously affect the availability of rail service for shipment of grain and farm inputs or would require rail subsidies. Greatly increased coal shipments by rail creates inconvenience and environmental deterioration in communities through which the trains pass. The pipelines could conserve oil both in shipping coal and in reducing costs of coal, thus facilitating substitution of coal for oil in generating electricity. The issue involves a complex system and a sophisticated benefit-cost analysis.

An Observation of Political Practice

The following are a few cryptic observations on the political process in practice relating to the rail service continuation decisions in Michigan from the vantage point of a member of an advisory council. The observations illustrate issues and problems in preference articulation. The problem of representation of taxpayer interests, a dispersed interest group, in contrast to the concentrated interests, is highlighted.

Michigan has about 900 miles of track under railroad service continuation subsidies. In addition, nearly 1,000 miles of line and 300 miles of car ferry service are either under abandonment petition or believed to be subject to abandonment. Estimated operating subsidies for 1978–79 were $16.7 million, and an additional $6.1 million was spent for rehabilitation projects on the subsidized lines.

My major observation is that a rail service continuation program is needed; that the discontinuation of rail service on all bankrupt and unprofitable lines which solvent lines wish to abandon would disadvantage large numbers of people, would be inequitable, and generally would fail to reflect preferences of Michigan voters. However, the political process as instituted in this case was not very effective in discriminating among projects, in making cost-effective decisions, or in planning the design of a long-run viable rail system.

Settlement Patterns

The settlement pattern issue is best illustrated by the case of a fourteen-county area served by three railroads. Two of these railroads were bankrupt and are currently operated by independent companies under a rail service continuation subsidy. The third is a solvent carrier with all lines in this area under petition for abandonment. Without subsidy or a declaration of public necessity requiring the solvent railroad to continue service, this area presumably would lose all rail service. The subsidized railroad which serves the major portion of the area has 245 miles of track, will receive an estimated subsidy of $3.5 million for 1978–79, and originates or receives 1,752 cars (about $1,997 per car load). The subsidy exceeded revenues by almost $2 million.

Cross-Subsidies

The solvent railroad has about 140 miles of track in this fourteen-county area under abandonment proceedings. Based upon the hearing evidence, costs exceeded revenues by about $1.5 million, and about 2,400 cars originated or terminated on the line. The state's formal position is opposition to the abandonment. If the solvent carrier is forced to continue service, the costs will not show up in the government budgets.

Rationalization

Analysis by Patrick and the technical staff of the Michigan Department of Transportation indicates that approximately 95% of the volume of originations and terminations in the area could be served by combining segments now operated by the three railroads, eliminating half the track mileage and costs.

Major barriers to such a proposal are that 4R Act funds cannot be used to subsidize a solvent carrier. The solvent carrier wants to abandon and does not want to operate under subsidy. A state proposal would weaken the case in opposition to the abandonment. Perhaps most important, transaction costs are high and the availability of federal funds relieves the pressure for effective action.

Ownership

A 104-mile segment of track is operated by a small, solvent carrier at a subsidy cost of about $1.3 million with 388 carloadings ($3,415 per carloading). The area served is not developed but does have a future potential; still, this level of subsidy is difficult to justify. Loss of rail service has been a threat for years, thus discouraging development. The solvent carrier has offered to guarantee service on the line without subsidy if the state would purchase and rehabilitate the line and grant the company a nonexclusive, permanent easement over the right-of-way—that is, for all practical purposes, give the line to the company. The cost would be a one-time investment of about $8 million. Thus, in the long run the government would save money, service would be improved, and uncertainty would be reduced. But such a project would set precedence and transfer property to a private firm. (The situation, as usual, is more complex than I have described.)

Substitute Service

A much less expensive solution to serve those shippers currently using this line and several others would be to subsidize truck-to-rail service. But acceptable decision rules for such a program have not been devised. It is, in fact, difficult to devise decision rules which would provide substitute service without subjecting the treasury to extensive claims by a large group seeking equal treatment.

Benefit-Cost Analysis

Individual line benefit-cost analysis used by the DOT staff estimated the impact of abandonment on local employment, income, and users' costs. The boundary question was not confronted. Energy budgets usually indicated that abandonment and a shift to truck for quantities now shipped would reduce energy consumption. Consequences for road and highway costs were usually negligible. Johnson, in a detailed rail disinvestment study of two Michigan lines, found that rationalization could reduce cost of service with negligible social impact. Benefit-cost analysis on rail segments will, I believe, influence decisions eventually, but are not easily introduced into the political decision process. The uncertainty of potential future shipments and developments is an important factor in political debate.

Public Hearings

Public hearings may produce some useful specific information about the problems of people immediately affected by a transportation project but reveal very little about tradeoff preferences for the majority of citizens. Over several years of hearings I never heard a presentation representing the interests of the general taxpayer. Similarly, legislators argue for economy in government and vote to restrict budgets in general, but almost always support a local group seeking rail service in their districts. The news media present editorials supporting economy in government but dramatize the problems of firms and areas threatened with the loss of rail service.

Implementation

The decisions on rail service continuation which counted the most—the design and

awarding of contracts—were usually done under time pressure. Funding was usually uncertain, making effective planning difficult. Rail planning and rail operations were in separate units. The planning unit complained that the plans and analysis they produced were not used, and operations complained that planning was always too late and inappropriate. Plans were never in the context of total transportation or even the total rail system but concentrated on line by line evaluations. No state group systematically considered the issue of settlement patterns. An annual plan satisfied the federal requirement to have a plan as a condition of funding.

An effort to establish a meta plan failed. It was not possible to adopt a time schedule for making critical decisions in a logical sequence. This was due in part to real uncertainty in regard to budgets and federal policy. Some argued that the 3R and 4R Act concept of limited federal subsidy designed only to facilitate adjustment and which would be phased out over a prescribed period should be taken seriously. Others believed this to be poor strategy.

Conclusion

My assignment was to identify issues and problems in articulation of preferences for transportation, not to provide solutions. The solutions lie in the political process itself, not with any one specialist. There is no unique optimum transportation system. I conclude that neither the market nor the political process is very effective as mechanisms for preference articulation for such complex products as the national transportation system. While good applied political-economic analysis will not produce a perfect system, it can make a useful contribution. To be useful, economic analysis must be tuned into the reality of the political system.

References

Baumel, C. Phillip. *The Local Rural Road and Bridge Problem and Alternative Solutions.* National Extension Transportation Task Force, Dep. Agr. Econ., Oklahoma State University.

Gerald, John O. *The Impacts of Transportation Regulations on Grain Movements and Marketing—Pro and Con.* Paper presented at North Dakota Grain Marketing and Transportation Seminar, 23 Jan. 1979.

Johnson, Marc A. "Market and Social Investment and Disinvestment in Railroad Branch Lines: Evaluation Procedures and Decision Criteria." Ph.D. thesis, Michigan State University, 1975.

Koenig, Herman E., and Thomas C. Edens. *Energy Economics: Foundations of Energy Policy.* Paper prepared for Second Energy Seminar for Michigan Legislators and Staff, 7 May 1979.

Patrick, John Michael. "An Economic Analysis of Improving the Viability of Rail Lines: A Michigan Case Study." Ph.D. thesis, Michigan State University, 1977.

Peterson, Everett E. *Transporting Western Coal: Railroads; Slurry Pipelines; or Both.* National Extension Transportation Task Force, Dep. Agr. Econ., Oklahoma State University.

Issues in Freight Transportation Regulation

Wesley R. Kriebel and C. Phillip Baumel

For the past decade some economists, and more recently some politicians, have taken the position that economic regulation of freight transportation should be reduced or eliminated. They suggest that removing regulated motor carriers from economic controls by the Interstate Commerce Commission (ICC) will encourage new entrants into the industry, lower freight rates, and improve service to shippers. The railroad industry and the U.S. Department of Transportation are advocating significant reductions in the economic regulation of railroad freight transportation. They argue that the railroad industry suffers from overcapacity, that it is unable to respond to price initiatives of exempt motor and barge carriers of agricultural commodities, and that ICC regulations interfere with efficient management of rail operations.

Railroad regulation developed in the 1850s–60s, when shipper allegations of unreasonably high rail rates, rebates, rate and service discrimination, and railroad pools led to agitation by farmers and merchants in the Granger territory for state laws to regulate railroads. Passed in ten states, these laws permitted rail rates to be established by state regulatory commissions or by state legislatures and prohibited long haul-short haul discrimination. In 1886, the United States Supreme Court held that a state could not control rates on interstate traffic. A year later, the Interstate Commerce Act (IC Act) established the Interstate Commerce Commission.

In 1917, the Car Service Act authorized the ICC to establish reasonable rail car service rules and to deal with car service emergencies. The Transportation Act of 1920 authorized the ICC to control railroad extensions and abandonments.

In the 1920s and early 1930s the trucking industry became overcrowded with small uneconomic units unable to satisfy the minimum standards of safety, service, or financial responsibility. Concurrently, shippers and communities were finding that motor carriers provided the transport service that accommodated the changing needs of the economy, including door-to-door freight service and reduced inventories. To assure that public demand for essential transportation service would be met, as well as to provide for a financially viable and stable motor carrier industry, Congress amended the IC Act in 1935, bringing most types of interstate, for-hire motor carriers under economic regulation. The philosophy of federal regulation was to create an orderly marketplace, without discrimination because of size or location, and to provide a common carrier system available to all shippers.

A special concession was granted to agriculture in the Motor Carrier Act of 1935. Carriers hauling unmanufactured agricultural commodities were completely exempt from any type of economic regulation. Justification was based largely on the nature of the movement of these commodities. They often are perishable and seasonal, and they require a large number of vehicles during an often short harvest season, thus not lending themselves to the common carriers of general merchandise over regular routes.

Against this historical background, does agriculture or anyone else still need economic regulation of freight transport, and if so, for what purposes and on what scale? This paper discusses the major issues of freight transportation regulation; carrier entry and exit, pricing, quality of service, and regulation of carrier operations.

Entry and Exit

The law requires that applicants for new or additional intercity motor-common-carrier operating authority must prove that the proposed service will be in the public interest. A certificate is granted generally when the ICC finds there is a public need for the service and

---

Wesley R. Kriebel is managing director, Research and Economics Division, American Trucking Associations, Inc., and C. Phillip Baumel is a professor of economics, Iowa State University.

Journal Paper No. J-9598 of the Iowa Agricultural and Home Economics Experiment Station, Project No. 2016.

the applicant is fit, willing, and able to perform properly the proposed service. The motor common carrier is legally obligated to accept all shipments of commodities it is authorized to haul and to serve all customers without discrimination in the territory it is authorized to serve.

Supporters of reduced motor carrier regulation claim that the difficulty of obtaining ICC operating authority might have prevented the development of an adequate number of firms, resulting in rates that are higher than they would have been under a deregulated system. According to the 92nd Annual Report of the ICC (U.S. ICC 1978d), more than three-fourths of the 16,800 regulated motor carriers were small, usually family-owned businesses with annual gross revenues of $500,000 or less.

Regulated motor carriers say the ICC is now ignoring the traditional criteria that have formed the basis for disposition of applications for common carrier authority as stated in the Pan American Bus Lines case (U.S. ICC 1936). The present wholesale granting of 95% of the truckload authority applications by the Commission (U.S. ICC, 1979b) is given as evidence that, essentially, entry has already been deregulated. The industry contends that if such action is appropriate, which it does not believe, then the ICC must seek congressional action and not merely toss aside the concept of entry regulation.

The regulated motor carrier industry seeks changes in the present law that would amend the criteria for issuance of operating authorities to include adequacy of service, ability and willingness of existing carriers to meet shipper needs, plus the energy effect on existing carriers of granting new certificates. The industry also advocates consideration of a reasonable broadening of commodity and route restrictions. The motor carrier industry would also redefine private carriage to permit intercorporate hauling for wholly owned subsidiaries and affiliates (Motor Carrier, Regulatory Improvement Act of 1979, H.R. 3549 96th Congress, 1st session, 20 June 1979).

Proposals have been made by some farm groups and the Carter Administration to expand the list of exempt agricultural commodities to include farm inputs and foodstuffs. Proponents argue that regulated carriers are not interested in the short-distance movements of fertilizer, feed, chemicals, and other agricultural supplies. This forces some agribusiness firms into the trucking business. Adding these items to the exempt list would, they claim, enable unregulated truckers to backhaul them. Proposals have also been made to expand the right of agricultural cooperatives to haul nonmember regulated freight.

The regulated carriers dispute these charges and counter further that to expand the exempt agricultural commodities list would allow those whose present business is agricultural hauling to enter the common carrier market in a pick-and-choose manner. Also, this would increase fuel consumption and empty miles. They claim the marketplace would be seriously disrupted, accurate and public market information on freight rates and carrier services would no longer be assured for shippers, the carriers would suffer financially, and the marketplace would become less, not more, competitive.

Empty backhaul mileage is said to result from regulation. But regulated motor carriers point out that empty mileage primarily arises from the inherent regional traffic imbalances and the use of specialized equipment. The ICC has estimated empty mileage for regulated route motor common carriers to be 7% (Glaskowsky, O'Neil, Hudson). It is difficult to fill one empty backhaul without creating another, because eliminating ICC entry regulations would not appreciably increase the amount of traffic.

The railroad industry and the U.S. Department of Transportation (Railroad Deregulation Act of 1979, U.S. Senate Bill No. 796, 23 Mar. 1979) advocate eliminating ICC controls on branch rail line abandonment and on railroad mergers and consolidations. The railroad industry contends that continued operations and maintenance of thousands of miles of light-density branch lines result in large operating losses. Much of this track would require large amounts of capital to be upgraded to handle the 100-ton rail cars. The industry contends that the losses would be magnified if they were forced to maintain and upgrade these tracks. Moreover, they state that because the present ICC abandonment procedures are lengthy and costly, only the most obvious cases for abandonment are brought before the ICC.

Shippers and communities located on branch rail lines argue that the loss of the branch lines would increase substantially costs and probably make it impossible for farmers to market their products and receive

production inputs. They claim that the poor condition of many branch lines is due to railroad neglect and that, with good service and track maintenance, the branch lines could be profitable. They further maintain that rail abandonment would threaten the very existence of their communities and add to the energy problem.

Railroad companies indicate that many branch lines are energy inefficient because of circuity, stop and start operations, and low traffic volume. They claim through trains and unit trains are more energy-efficient than branch line operations. While they concede rail abandonment will increase fuel consumption by trucks hauling the product further to nearby main lines or upgraded branch lines, the fuel savings on the energy-efficient main line operations will more than offset the additional fuel consumption by trucks and will actually reduce total fuel consumption. Moreover, the railroad industry maintains that research has shown that communities located on abandoned branch lines have not declined and many have continued to prosper.

Pricing

As part of their public service obligation, the regulated motor and rail carriers must charge rates that are reasonable and not unjustly discriminatory. They are required to disclose rates publicly. Shippers and receivers contend that knowledge of what transportation rates will be next week, next month, and six months from now is important to a small business owner who must often compete in the same market with a large organization but does not have the staff resources to gather and analyze rate information. With no discounts, all users—large and small—pay the same prices for similar services.

The law provides legal antitrust immunity for collective rate making conducted through tariff bureaus (Reed-Bulwinkle Act, 49 U.S. Code Rev., Sec. 10705, 1948). Both carriers and shippers cooperate in the filing of proposed changes to existing tariffs, subject to approval or disapproval by the ICC. Rate making procedures are designed to insure that unjustified changes cannot be made easily. Proposals for general rate increases are reviewed by the ICC, which can, on its own motion or upon the complaint of any shipper or interested party, decide to suspend the new rate until it determines whether it is reasonable or if it is discriminatory.

Proponents of increased price flexibility claim that open price competition will yield lower rates and improve efficiency. The current rate setting process is said to reduce the incentive for carriers to improve productivity and hold down costs. Rates based on the cost of providing the services, instead of artificial rough-system averages, are viewed as the cornerstone of future transport policy.

The regulated motor carrier industry position is that open entry and freedom to negotiate all rates would create destructive competition in the industry. Entry of new firms undoubtedly would take place in the truckload market. The amount of truck traffic, however, would not expand as rapidly as trucking capacity, leading to severe rate competition on truckload movements, with revenues failing to cover total costs for many carriers. The next phase would be financial difficulty of the local carrier and rate increases or termination of high-cost, less-than-truckload service. It is said there would be chronic over-capacity, a high turnover of trucking firms, reduced financial and operating reliability, and greater difficulty in tracing shipments and in collecting lost or damaged freight. The industry maintains that the process of collective rate making is absolutely essential to the maintenance of a stable, cost-effective, fuel-efficient, freight transportation system. Shipper groups also endorse collective rate making as the only practical way to make sense out of the hundreds of thousands of rates on items to be transported to some 60,000 communities throughout the United States.

The motor carrier industry's legislative proposal for regulatory improvement calls for creation of a zone of reasonableness, including a no-suspend zone of 7% (decrease or increase) annually, for a five-year period.

The railroad industry cites its continued low earnings to support its request for rate flexibility designed to meet competition, to take prompt advantage of innovation, and to market rail service aggressively. The average return on investment in the railroad industry in 1978 was 1.6%, seven railroad companies lost money, and no major railroad had more than a 9% return on investment (Association of American Railroads). The major changes in rail-pricing regulation proposed by the railroad industry include:

(*a*) Ability to establish rates by contract without review by the ICC. The purpose of the contracts would be to provide a more precise definition of the transport needs of the shipper, to base the rate more on costs of the movement, and to define more precisely the shipper and carrier risks and requirements. These contract rates would be filed with the ICC or another government agency.

(*b*) Ability to publish seasonal and peak demand rates without notice. The Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act) provides for seasonal and peak demand rates with a thirty-day notice of publication or cancellation (90 Stat. 31, P.L. 94-210, 5 Feb. 1976).

(*c*) Ability to quickly change the division of rates among railroad companies to reflect changes in costs.

(*d*) Ability to establish general rate increases to provide protection against inflation.

(*e*) Ability to continue joint rate requirements among railroad companies.

Supporters of continued ICC controls over railroad rates point out that the 4R Act provides for establishment of both seasonal and demand-sensitive rates, and that the railroad industry has failed to use this price flexibility. The railroad industry counters that this flexibility is of limited value because of the thirty-day notice requirement for publishing or canceling the rates. Exempt commodity truckers and barges have no such requirement. This enables exempt carriers to charge high rates during peak periods and to quickly reduce rates to hold traffic during periods when the volume of traffic declines. Moreover, the major seasonal rate proposal arising from the 4R Act is in protracted litigation, which likely will be settled by the U.S. Supreme Court (U.S. ICC, 1978c).

Shippers supporting regulation of railroad rates cite the need for stable rail rates as a prerequisite to product pricing. They are fearful that the contract rate provision would favor the large rail user over the small rail user. The railroad industry replies that many agricultural shippers have adjusted successfully to the rate fluctuations of exempt truck and barge carriers and have increased continuously the volume of their products shipped by these modes.

The rail rate structure has influenced agricultural and industrial locations and relocations. The cost, quality, and availability of transportation is critical to the competitive position of agricultural industries in different regions. Rail users in some regions allege that they still face both rate and service discrimination by railroad companies. Whether these rail users are really being "gouged," or whether they are simply paying the full cost (or even less than the full cost) of transporting their agricultural outputs and inputs, given their geographic and light-density location, can only be answered with more refined analyses than are presently available. The important point is that some users think they are being overcharged and other users feel that less regulation of rail prices will recreate the potential for discrimination. Although these users are basically in favor of increasing the efficiency of the railroad industry, they indicate that they will support increased efficiency through less regulation or regulatory reform only if some assurance of protection is provided in terms of rates and/or service that both shippers and railroads can live with. Thus, protection of the so-called captive rail user is a major regulatory issue. While many people are convinced that some users are captive or potentially captive to railroad market power, there is little agreement of precisely what is a captive rail user or what protection should be provided to the captive user under alternative levels of reduced rail regulation.

The railroad industry, while agreeing that some users may be captive to railroads, argue that railroad companies face intra- and inter-modal competition for the products they carry. Moreover, the products they carry face market competition from products produced in other regions. Thus, to raise rates to the point that would drive their producers out of business would, in the long run, lead to the further erosion of traffic from the railroads. They would clearly be better off hauling products at a rate that would generate traffic on their lines. Thus, one potential type of captive-user protection would be to provide a guaranteed rail car supply to captive rail users.

A little noticed issue related to railroad rate flexibility is the commodity clause of the Interstate Commerce Act. This clause prohibits carriers from transporting property it owns except that used in the business of the carrier. Repeal of this clause could enable a shipper the opportunity to sell products at the point of origin to the railroad company and buy them back at the destination at a price that could reflect a discriminatory freight rate.

Quality of Service

The regulated motor carrier industry believes that eliminating economic regulation would introduce uncertainties into the cost and availability of motor carrier service. Small businessmen likely would be faced with the prospect of ordering in larger quantities with less frequent service, thereby incurring increased storage facility and carrying costs and higher total physical distribution costs.

The motor carrier industry believes that price and entry controls have helped to achieve economic and social objectives that free market forces could not always assure. Over time, large and small businesses have been able to locate with the assurance that there already existed, or would soon exist, timely and continuous truck services. Thus, accessibility to markets with certainty may be an implied economic and social benefit of transport regulation.

Although small, rural communities probably would continue to be served by trucks in the absence of regulation, the uncertain issue is whether these towns would be served adequately and/or at higher prices. If cross-subsidization exists under regulation, many small communities may discover that their transport costs have increased sharply after reduced regulation. The regulated interstate carriers believe the most profitable firms would compete only for freight in the high-volume traffic corridors. To the extent that marginal carriers survive, they likely would be left to serve the smaller towns and rural areas. If true, relaxing motor carrier entry requirements and permitting unregulated rates would eliminate the common carrier obligation to serve all who need and want service with reasonable dispatch and with adequate equipment. They further argue that in the absence of regulation, overcapacity and inadequate revenues would lead to deterioration of safety standards, evasion of safety regulations, financial irresponsibility, and generally unsatisfactory service.

Regulation is blamed by critics for protecting the status quo, stifling new technology, and limiting the range of rate and service choices. The implication is that a significant number of shippers have been overcharged for current levels of service. It is alleged that, if the common carrier system were more competitive and were to offer a diversity of services, then overall physical distribution would be improved and consumer prices would be lower.

The motor carrier industry contends that a major test of the variety and quality of services offered by regulated motor carriers is the attitude of users of the service. Numerous shipper surveys show general satisfaction with motor carrier service and support the concept of regulation (Wagner; Constantin, Jerman, Anderson).

Railroad companies cite the need for shortening the time required for ICC decisions on railroad mergers and consolidations. These mergers and consolidations are needed to reduce excess rail plant by providing for joint use of main line track and switch yards. Moreover, they are needed to consolidate rail services. Individual railroad companies say it is difficult to control service quality on interline traffic in the absence of mergers and consolidations. The railroad industry argues that railroad mergers should be handled in the same manner as mergers of other industries. That is, if a merger is found to be anticompetitive, it is prevented. However, rail users and labor leaders contend that additional mergers and consolidations would reduce or eliminate carrier competition and would result in a reduction of jobs and increased rail abandonment.

Control of Carrier Operations

In addition to its control over pricing, entry, and exit, the ICC can influence rail carrier operations. It can control rental rates on freight equipment, charges for accessorial services, the way cars must be routed, the number of cars and locomotives assigned to specific commodities, the number of cars assigned to unit trains, which rail cars will be repaired, and the way cars shall be moved. For example, ICC Service Order 1304 required railroad companies to place a maximum of 20% of its covered hopper fleet in unit grain train service (U.S. ICC, 1978a). The order was issued in 1978 because small grain shippers complained that a large share of the fleet was assigned to unit grain trains. Unit grain train shippers and railroad management argued that each unit grain train car will haul at least twice as much grain as a car in regular train service because of faster turnaround times. Therefore, if the objective is to increase

the amount of grain transported, more—rather than fewer—cars should be assigned to unit grain trains. Service Order 1304, which was cancelled before the car shortage period ended, is a classic example of the issue of efficiency versus equity.

ICC Service Order 1309 requires railroads to place, remove, forward, clean, weigh, and if needed, repair cars within twenty-four hours (U.S. ICC 1978b). Railroad companies complain that it is impossible to comply with this order in all cases because of missed connections, congested ports and terminals, plugged grain elevators, weather, and other uncontrollable events. As a result of the order, some cars are moved in the wrong direction, or moved from the origin point while still empty or from the destination while still loaded.

Car Service Order 1322 required that 70% of all covered hopper cars and 50% of all 40-foot box cars of twelve Midwest railroad companies must be placed in grain service (U.S. ICC, 1978b). The intent was to help solve an acute grain car shortage. The Missouri Pacific Railroad Company generally uses most of its covered hopper fleet to haul fertilizers and other chemicals. Yet, this service order forced most of its hoppers into grain service. The service order was quickly changed after the ICC received vigorous protests from shippers of fertilizer, chemicals, cotton, and sugar that this service order was simply creating a car shortage for nongrain shippers.

Critics of ICC-car service orders contend that the service orders are issued with little analysis or knowledge of the impacts or benefits and costs of the orders. Recently, one ICC commissioner stated: "Over the years, the results of using our emergency car service authority have been extremely mixed. Indeed, sometimes I wonder whether our activities may have done more harm than good!" (Christian).

In the current fuel crisis, the issuance of Special Order No. 9 by the Department of Energy was, in essence, a similar effort to resolve the problem (U.S. Department of Energy). This order established the priority of middle distillate consumption by farmers and haulers of perishable food products. Other high fuel users, specifically the independent truck operators, found the regulation did not provide adequate fuel at an acceptable price level for their perceived needs, resulting in severe operational instability.

The ICC granted a special fuel surcharge to allow for expedited recovery of increased costs (ICC 1979a). This order, however, only applied to the independent operators who contract with regulated motor carriers. The carriers of exempt agricultural commodities do not have an institutional framework for such recourse.

Conclusion

The freight transportation regulatory system is currently under severe criticism. Alternative proposals are being offered and debated by the carriers, the shipping public, the body politic, and economists. The regulated motor carrier industry supports the present regulatory system but is recommending regulatory reforms that it believes will make the system more efficient. The basic industry position is that the country needs a responsive motor-common-carrier freight system, and without regulation such a system is impossible. Some spokesmen of exempt truckers favor further relaxation of entry and price controls. The railroad industry generally favors elimination of much of the railroad regulation. Rail and motor carrier users are found on all sides of the issues. Small community leaders fear the effect of major changes in freight regulation on their towns.

Information on the likely impacts of major changes in the regulatory system is needed to help resolve these disagreements. A significant number of studies have been done on the impact of rail abandonment on shippers and communities. Little research is available on the potential impacts of increased price flexibility of railroads and motor carriers, or relaxation of entry controls for the motor carrier industry, of rail mergers and consolidations, of ICC rail car service rules, and of other regulatory issues on various groups of shippers, carriers, and communities. Little has been done to define the extent to which groups of rail users are captive to the railroad industry. Much of the speculation on the impacts of relaxation of railroad regulation focuses on the impacts of large and small agricultural shippers. These discussions typically fail to define what is large and what is small, and they are often blurred as to who is the shipper. For example, is the grain farmer or the local elevator the shipper? This lack of information presents a unique opportunity to agricultural economists for research to help resolve the conflict on regulatory change.

References

Association of American Railroads. Xeroxed summary table for the year 1978. Washington, D.C., 1979.

Christian, Betty Jo. Remarks at Conference on Deregulation of Transportation: Remedy or Roadblock? Sponsored by the Syracuse University's Salzberg Transportation Institute, New York City, 18 May 1979.

Constantin, J. A., R. E. Jerman, and R. D. Anderson. "Rail, Motor and Shipper Opinions on Regulatory Issues." *Transportation J.* 17(1977):40–50.

Glaskowsky, Nicholas A., Jr., Brian F. O'Neil, and Donald R. Hudson. *Motor Carrier Regulation*, Appendix 1. Washington, D.C.: American Trucking Assoc. Foundation, 1976.

U.S. Department of Energy. Special Rule No. 9, part 211, Petroleum Allocation Regulations, 15 May 1979.

U.S. Interstate Commerce Commission. *Distribution of Covered Hopper Cars*. Corrected Service Order No. 1304, Washington, D.C., 1 Mar. 1978a.

———. *Distribution of Grain Cars*. Service Order No. 1322, Washington, D.C., 12 Apr. 1978b.

———. *Expedited Recovery of Fuel Cost*. Ex Parte 311, Washington, D.C., 26 June 1979a.

———. *Initial Report of the Motor Carrier Task Force*. Washington, D.C., May 1979b.

———. *Interstate Commerce Commission v. Seaboard Allied Milling Corp., et al.* S. Ct. No. 78-597, 570 F 2nd 1349 (8th Cir. 1978). Washington, D.C., 1978c.

———. *Motor Carrier Cases*, 190, 203. Washington, D.C., 1936.

———. *92nd Annual Report*. Washington, D.C., 1978d.

———. *Railroad Operating Regulations for Freight Car Movement*. Revised Service Order No. 1309. Washington, D.C., 12 Apr. 1978e.

Wagner, William B. "Shippers Vote Down Regulation." *Distribution Worldwide*. Jan. 1979, pp. 37–39.

Issues in Freight Transportation Regulation: Discussion

James Springrose

Shaffer poses many questions which are relevant but perhaps above all, controversial. They have been in debate, in the legislature, studied, studied again, and otherwise under consideration for a long time. And some progress has been made . . . some solutions have been implemented. Those which work best are usually sponsored and supported by the private sector as opposed to the government.

For example, intermodalism has been a fact of life whose adolescence passed in the 1950s. Industry has been quietly but effectively utilizing the concepts of intermodalism for a long time. Its progress has been stimulated by the economics of transportation and distribution. Furthermore, trailers-on-flatcars and containers are but a small component of intermodal activity already in use. I see very little need to change or expand this motivation. Rather, I see intermoldalism expanding on its own momentum.

Above all else, government preference expressed through the political process should be reduced to a minimum, rather than expanded. These preferences often follow special interest desires and become pork barrels which either overstate the benefit-cost ratios (e.g., St. Lawrence Seaway and Arkansas River Project), or overregulate to achieve exaggerated priorities.

We have come to learn and should be willing to admit that there are excesses (emphasis "excesses") in the regulation of commerce within and beyond the transportation sector which fail to contribute to justified national objectives. The excesses of regulation only contribute to inflation.

These excesses are but examples which support Shaffer's position that "the political process is not a very effective mechanism for citizen preference articulation. It is difficult to express efficiently preferences in the political process and there are problems in designing bureaucracies to be responsive to preferences."

With regard to the captive shippers, whoever they might be, I believe their vulnerability rests in the availability of service rather than in the level of rates. I see little value in having low rates if one cannot obtain service to reach market outlets. In most discussions about captive shippers, the impact of freight rates on their competitive posture has been overdramatized.

Likewise, I believe rail car shortages have been overdramatized. To be sure, cars are not able to meet demand but our studies suggest that when the cars now on order are added to the existing fleet, the supply could and should be adequate through 1985. Any more will only clutter up the system. The focus should be on productivity improvement instead of fleet expansion. Self-imposed speed restrictions because of poor trackage, deterioration and inadequacy of classification yards, short circuits of locomotive drive-motors caused by snow, and antiquated work rules contribute far more to car shortages than does the size and number of the rolling stock.

Motor Carrier Deregulation

As to the paper by Kriebel and Baumel, I believe it is unwise on the issue of truck deregulation to reach conclusions which are based on experiences, real or imagined, of the 1920s. Reliance on historical experience precludes the impact of technological advance on the industry in the interim period. Much of the preregulation service deficiencies were caused by mechanical failures long since corrected and by inadequate roadways long since improved.

Second, those who support continuation of the regulatory process should articulate that support in ways which lend credibility to their position. For example, dismissing the empty mileage issue with deadhead mileage estimates

---

James V. Springrose is Vice-President of Transportation for Cargill, Inc., Minneapolis, Minnesota.

for regular route common carriers represents the classic example of the tail wagging the dog. Seven percent is a nice low ratio for that group, but an overall ton mile evaluation suggests the industry as a whole is burdened by much higher percentages (26.3% to 27.9%) of deadheading which just might represent an unjustifiable waste of energy and other costs to the distribution system. Interstate Commerce Commission. *Empty/Loaded Truck Miles on Interstate Highways During 1976,* see table VI.)

With those cautions I will sidestep—neatly, I hope—the issue of motor carrier regulation or deregulation.

Rail Abandonment

In the fifty states which comprise the United States, there are 39,019 communities without railroad service. This is 64% of all communities in America and most of them have never had railroad service. (Motor Vehicle Manufacturers Association, *Motor Vehicle Facts & Figures '77.*) For example, of the 207 communities in Hawaii, not one has railroad service; 90.7% of Alaskan communities do not have railroad service. Before you conclude that these are isolated states and extreme examples: there is Maryland, the birthplace of United States railroads—it is 88.8% non-rail served; and Delaware is 86.5%, Pennsylvania, the home of ConRail, is 76.8% non-rail served.

The average is reduced by lower percentages of non-rail service in the Granger States. However, these comparisons cast serious doubt on the conclusion that abandonment of rail services will "probably make it impossible for farmers to market their products and receive production inputs."

Rail Pricing

The principal thing railroads should learn, in their zeal to obtain freedom for peak demand pricing which they believe barges and exempt trucks enjoy, is that those they envy are usually bound by price and service contracts on large segments of overall capacity. Therefore, the peak demand escalations in these other modes are available for only a relatively small percentage of their business.

From the shipper's point-of-view, demand elasticity of most products is not governed by freight rates. Therefore, there is little hope that lower rates in the "off season" will stimulate new demand. As a result, most shippers view this approach to railroad pricing as simply a gimmick to increase rates during times of shortages.

References

Interstate Commerce Commission. *Empty/Loaded Truck Miles on Interstate Highways During 1976.* Washington, D.C.

Motor Vehicle Manufacturers Association. *Motor Vehicle Facts & Figures '77.*

Issues in Freight Transportation Regulation: Discussion

Ken L. Casavant

The two papers I will discuss today appear to be quite different in approach to the subject matter of transportation policy. Shaffer speaks about the problems of instituting market and political mechanisms for articulating preferences for transportation. Kriebel and Baumel discuss issues in freight transportation regulation from the viewpoint of carriers, shippers, consumers, and policy makers. Shaffer's presentation leads us to a new slant in mostly traditional policy questions, while the Kriebel and Baumel paper summarizes traditional "positions" associated with the deregulation question. But, the papers are not as different from each other as first glance would suggest because both focus on the question of how the conflicting preferences should be resolved in the area of transportation policy, specifically regulation. This commonality is reinforced by the decision of the authors only to raise questions in their presentations rather than provide answers or even a framework for seeking out solutions. I do hope this was the "charge of the paper" received by authors because I do not, as I will indicate below, believe it is the state of affairs in transportation policy.

Shaffer offers us a traditional, nonrigorous treatment of pricing, regulation, and ownership. It is in the areas of jurisdictional boundaries, settlement impact, and energy-market problems where his known innovativeness and perspective became evident. Nowhere is the question of jurisdictional boundaries more evident than the current discussion, at the federal level, of truck weight and length variation in state regulations. Preference articulation in this instance may be achieved by a federal mandate on weight and length to be settled in a court case evaluating "states rights." A point worth repeating is Shaffer's assertion in his discussion on settlement impact, that decisions in regard to location of activity made by individuals will not achieve aggregate settlement patterns consistent with preferences of those individual decision makers. Public transportation's dependence on high-density settlement pattern is a bit of "Catch-22"; we will not necessarily get high density if public transportation and other services are not available, and yet public transportation is often dependent on high-density areas already being in existence before an investment will be made by appropriate decision makers.

In summary, I do concur that the mechanics of the political-economic system is indeed a complex system. The economic signals are often messy, potentially misleading, and yes, even missing. It is necessary to incorporate economic and political externality questions back into the marketing system if preference articulation is to be achieved.

But, it is not appropriate to give up on the process or view it in the rather pessimistic approach contained in the Shaffer paper. The Environmental Protection Agency, agricultural land preservation activities, regulation modernization, etc.; all of these are micro-components of a dynamic system that is working and does offer the mechanics to achieve, albeit marginally at times, preference articulation. Finally, a desirable activity of academic researchers is to develop an investigative framework in this area so that "asking questions" does not continue to be the conceptual methodology this paper seems to suggest it is.

The second paper today can be considered a case study in preference articulation; namely, what are the issues and desires associated with the timely question of freight transportation regulation? The Kriebel and Baumel paper is an excellent discussion of the perceived desires of proponents and opponents of various issues within transportation deregulation. I was disappointed not to find in the paper what Kriebel and Baumel felt about the issues since both have done substantial research in the area.

When the authors review the background,

Ken L. Casavant is an associate professor in the Department of Agricultural Economics, Washington State University.

under the issue of entry and exit, of the agricultural exemption they fail to point out one goal that I feel has been fulfilled—the fact that the exemption allows transportation capacity to be used very efficiently in a geographic and temporal sense. Exempt truckers move throughout the United States following seasonal markets achieving a high-loaded backhaul percentage and providing responsive service to the agricultural producer. Also, the question of deregulation should not necessarily be considered a 0 or 1 dummy variable; we have seen substantial administrative deregulation by the ICC even while legislative deregulation is being considered and undertaken.

The discussion on quality of service was based almost solely on benefits and costs of mergers. Yet studies available in the literature have shown transit time and variability of transit time to be the operational quality of service variables considered by shippers. This relationship could have been developed further.

The overall conclusion of the Kriebel and Baumel paper is that "information on the likely impacts of major changes in the regulatory system is needed to help resolve these disagreements." My contention is that much of the general information already has been produced, and that the questions raised in their discussion seem to ignore this work while projecting the image of a virgin field of policy analysis. The appropriate discussion is no longer "what do the people feel," but what further information on more specific questions is needed to achieve complete articulation. Studies have resolved many of the issues or positions discussed in these papers. It is now time to focus on specific remaining areas of contention, areas where the lack of mechanics of preference articulation are further hampered by the lack of definitive data.

Issues in Freight Transportation Regulation: Discussion

Lynn W. Robbins

In discussing preference articulation, Shaffer points out that "every unit of government . . . is involved in transportation. . . . The cost and benefits of a decision by one unit which accrue to other units are often not taken into account by decision-making units." Shaffer apparently is suggesting a systems solution to the multigovernmental unit problem. However, the transportation policy problem fails to meet two and possibly all three of the preconditions necessary to the systems approach "(*a*) . . . aims and goals of the system are well defined and recognizable if not quantifiable, (*b*) . . . the decision making process in the real system is centralized and fairly authoritarian, and (*c*) . . . a long range planning horizon is possible" (Manetsch and Park, p. 6a). The transportation system's aims and goals may be well-defined in the short run but change and fluctuate according to the varying powers and clout of interest groups in the intermediate and long run. Transportation decision making in any situation, short of nationalization, is neither centralized nor authoritarian. Certainly in a democratic society a long-range planning horizon is very unlikely.

Shaffer gives numerous rail examples of why total systems approach solutions have been inoperable in the face of regulation (e.g., one solvent rail line could not be subsidized as part of an "optimal" three-line solution). He presents examples where first, second, and even third best solutions were not implementable, and yet the need for systems or total network-oriented research remains. At least those efforts intended to direct policy decisions should be multimodal in nature.

Policy-directing systems research should include a prestudy political feasibility test as well as pretests for physical, financial, and economic feasibility. Certainly a good researcher would be unlikely to analyze the impacts of a solution that was not physically implementable. The guidelines for determining political feasibility are not as clear. However, the political feasibility test remains necessary in order to determine, *ex ante,* whether the results will be implemented directly, utilized to educate policy makers, or simply entered into as an academic exercise.

"To be useful," Shaffer concludes, "economic analysis must be tuned into the reality of the political system." He provides us with numerous researchable questions and implied answers that deserve emphasis. A few are liberally paraphrased here in the form of statements.

(*a*) Overhead cost allocation theories may exist that would allow market rate making where, now, regulation is supposedly needed. The implication is that the systems problem can be cured with a proper orientation to decision theory.

(*b*) Government-owned rails and deregulated entry could enhance private rail firms' responsiveness to shippers and eliminate the need for rate regulation.

(*c*) Multimodal transportation firms could be effective.

(*d*) Multimodal regulatory agencies could enhance efficiency.

(*e*) Many other sound researchable questions are presented with respect to coal-slurry pipelines, unit trains, and settlement patterns.

Kriebel and Baumel's "Issues in Freight Transportation Regulation" presents additional researchable questions. They ask the question, " . . . does agriculture or anyone else still need economic regulation of freight transportation, and if so, for what purposes and on what scale?" The authors pose this question and leave it unanswered. They present arguments used by proponents on both sides of the deregulation issue. Even though the authors do not tell us whether economic freight regulation is needed, a review of their remarks cause this respondent to feel the need to further emphasize justifications for deregulation.

When it comes to pricing, the regulated in-

Lynn W. Robbins is an associate professor in the Department of Agricultural Economics, University of Kentucky.

dustry justifies the need for collective rate making to maintain "a stable, cost-effective, fuel-efficient freight transportation system." It seems, however, that the essential ingredient is price information and not rate making. It is not difficult to argue that collective rate making is one "way to make sense out of the hundreds of thousands of rates on items to be transported to some 60,000 communities throughout the United States." It is especially difficult, however, to argue that it is the only practical way. Perhaps the ICC or some other regulator could assist and promote locality or commodity-oriented price information groups if rate boards could not be simply transformed into rate information boards. The unregulated market cannot work without good price and information flows. Information flows are not a natural outgrowth of an unregulated market economy. Consequently, it seems that information discovery should remain as one of the main emphasis areas for regulation.

One of the major problems highlighted by Kriebel and Baumel is that regulated carriers compete against exempt carriers. Regulated carriers cannot, like exempt carriers, charge high rates during peak periods and then reduce them quickly to keep their traffic. Western Kentucky's grain-exporting industry provides a case in point. Preliminary results from a study of that area indicate that an artificial shortage of carriers exists (Richardson). Although these are preliminary results and not yet verified, enough barges and rail cars apparently were available so that together the total shortage should have been no more than 5% or 10% instead of the 50% that was reported. The solution is either more or less regulation. More legislation would be required to keep the barge industry from skimming the market during the grain season or less regulation to allow railroads to implement seasonal rates.

Obviously, there is no current solution as to which is best, regulation or deregulation. Arguments for deregulation have been presented as a balancing tool. Drastic deregulation is just as disruptive as drastic regulation (e.g., nationalization). Anything but marginal changes from the status quo are too difficult to predict and are more likely to reduce rather than improve existing regulations. More unsubstantiated political biases become involved when major changes are initiated by uninformed actors.

An educational rather than empire-oriented policy orientation is needed. Our political problem is not so much that we implement poor policies, but rather that they are left intact. That is, poor policy is not replaced but rather corrections are attempted through countervailing policy.

Finally, this session's title and the titles of its papers make a rather disturbing comment with respect to the state of our profession and the topic of transportation policy. As researchers, educators, and practitioners, we should be defining researchable problems and mapping out paths to their solutions rather than simply enumerating the issues. Thankfully, the authors have done more than enumerate issues. Transportation policy will be made and implemented whether or not we provide the basis for those decisions in the form of sound research.

This is in no way a critique of papers presented in this session. It is improper to criticize authors for doing well what they were assigned to do. Let us not linger on the issues, however, now that we know them; but, rather, begin the search for solutions.

References

Manetsch, Thomas J., and Gerald L. Park. *Systems Analysis and Simulation with Applications to Economic and Social Systems, Part I*, 3rd ed.. Dep. Elec. Eng. and Systems Sci., Michigan State University, August 1977.

Richardson, James E. "Transportation Policy Impacts on Kentucky Grain Exports." M.S. thesis, University of Kentucky, 1979.

Agricultural Trade Issues among Pacific Ocean Countries (Lyle P. Schertz, ESCS USDA, Chairperson)

Changing Patterns of World Trade

Dale E. Hathaway

Commodity forecasting is a risky but often highly profitable business for private traders. It is equally risky, in a different way, for public officials and never profitable since most people tend to remember the public official's errors and forget the times he was correct. Thus, I shall avoid forecasting and instead examine likely future trends based upon some facts, some extrapolation of the trends of the last three decades, and some personal observations which may be subject to difference of opinion.

For two reasons I will focus my comments on a few widely traded agricultural commodities in which the United States has a major interest. One is that these are products about which I presume to have some knowledge; the second reason is that the nature of production, storage, and consumption of these agricultural commodities differ sufficiently from other primary commodities to warrant separate treatment. Even with these limitations, I would hope to be able to evoke some useful discussion and thought about future problems and policy issues.

The basic points I hope to make are (*a*) trade flows in many of these commodities have changed drastically in the past three or four decades; (*b*) the behavior of countries which play an increasing role in commodity trade results in greater uncertainty and instability in world markets for most of these commodities; (*c*) traditional adjustment mechanisms no longer function satisfactorily and as a result the adjustments fall on relatively small groups; and (*d*) given these circumstances and the unwillingness or inability of certain groups to tolerate the prospective situation, new institutional mechanisms for adjustment must be found as rapidly as possible.

Because I believe the way world commodity markets operate is a function of the policies and actions of participant nations in those markets, I will begin by reviewing the levels and composition of trade in agricultural commodities in which we have an interest. I will discuss trade trends in wheat, coarse grains, sugar, soybeans, cotton, and meat and animal products. These products currently account for 90% of United States agricultural exports, thus they are of major interest. I have classified countries into three categories—developing market economies, developed, and centrally planned, recognizing that the latter category includes both rich and poor countries.

Review of the Level and Composition of Agricultural Trade

Let me start my discussion with grains, namely wheat and coarse grains, commodities in which we have a significant export interest. As one looks at the data on world trade in these grains there are two factors that sharply distinguish them from many other internationally traded commodities and that have significant implications for the future of the grain trade.

The first is the major expansion, indeed one might almost suggest explosion, in the level of trade in both wheat and coarse grains over the last four decades. World trade in wheat, for instance, during the period immediately prior to World War II averaged less than 17 million metric tons per year. In the immediate post-World War II period trade in wheat increased by about one-third, with most of that increase occurring after the 1950s.

Starting with the 1960s, there have been substantial increases in world wheat trade. Using 1960 as the base year, we now find that the average world trade in wheat in the last

---

Dale E. Hathaway is Undersecretary of Agriculture, International Affairs and Commodity Programs.

This paper is adapted from remarks prepared for the Conference on Agricultural Marketing Policies for the 1980s, Perth, Western Australia.

The author is indebted to Gary Williams, U.S. Department of Agriculture, for the statistical work, and to Dr. G. Edward Schuh for comments.

three years is double that of the early 1960s. To briefly summarize, there was an approximate doubling of world wheat trade from the late 1930s until approximately 1960. Since that time, in less than two decades there has been another doubling of wheat trade and, it should be noted, current record levels of wheat trade have been maintained despite concurrent new world records in food grain output. Indications suggest that we can expect continuation of the increase in these trade flows.

The rate of increase in world coarse grain trade has been even more rapid than world wheat trade. Prior to World War II, coarse grain trade was reported somewhat below wheat trade, at about 15 million metric tons per year. Immediately after the war and continuing through the 1950s, there was no appreciable growth in coarse grain trade, unlike the growth in wheat trade. Starting, however, in the 1960s and continuing almost without interruption, there has been a veritable explosion in coarse grain trade which is now approximately six times the pre-World War II level and more than three times the 1960 level.

The second important element relating to world trade in grains is not only its growth, but the change in who exports and who imports. In the case of wheat prior to World War II, the developed market economies accounted for 60% of the exports and for two-thirds of the imports. In other words prior to World War II, more than half of world wheat exports originated in developed market economies, namely North America and Australia. Importers were mostly the developed market economies. After World War II this situation drastically altered. The trend is clear and there is no indication that it is changing. Throughout the post-war period and continuing to the present time, the proportion of exports furnished by developed market economies has grown steadily; they now provide more than 90% of total world wheat exports. Conversely, whereas the proportion of developed market economy imports has dropped from three-quarters to one-quarter of total wheat trade, the developing countries now account for half or more of all wheat imports and the centrally planned economies account for a quarter of all wheat imports.

For coarse grains, the trend in market shares has both some parallels with wheat and some important differences. Prior to World War II developing market economies exported nearly 60% of all coarse grains entering the world markets. The centrally planned economies provided another 20%. Thus, the developed market economies provided less than 20% of world coarse grain exports forty years ago. At that time the major importers, in fact virtually the only importers, were the developed market economies which imported 85% of all coarse grains entering world markets. During the prewar period, the developing market economies accounted for only 2% of the coarse grain imports while the centrally planned economies accounted for about one-eighth of the imports.

Looking at the post-World War II period we see a new trade pattern has evolved steadily and consistently. The developed market economies, namely North America and Australia, increasingly have come to dominate exports of coarse grains to the point where they now account for more than 80% of the exports of coarse grains entering world markets. This has been accompanied, as might be expected, by a steady decline in the proportion of exports coming from both centrally planned and developing countries.

A marked shift in the import pattern for coarse grains has also occurred. During the post-World War II period the advanced or developed market economies show a steady and continuing decline in the proportion of coarse grain imports, and if one removed Japan from these statistics the decline would be even more apparent. Concurrently, the developing market economies and the centrally planned economies have increased their imports of coarse grains.

To summarize the changing trade patterns for these two major grains, we have seen the developed market economies rapidly become the major source of exports while the developing market economies and the centrally planned economies have become the significant grain importers during the post-war period.

Soybeans

Let me discuss briefly another major traded agricultural commodity—soybeans and soybean products. As in the case of wheat and coarse grains, world trade in soybeans has grown tremendously. Prior to World War II, soybean exports were dominated by China, a developing country, and the developed market economies were the major importers. Since World War II there has been a sharp change in

exporters, but the importers have only recently begun to change. Since World War II the advanced market economies, namely the United States, have held a dominant position in world soybean exports, while Brazil and Argentina have replaced China as the only other exporters of consequence. The developed market economies, however, are still largely the importers (in fact, more than 80%). However, the centrally planned economies have been importing significantly more soybeans since about 1960.

Wool and Cotton

Now let me turn to trade in two other commodities, namely wool and cotton. Here we have commodities in which world trade patterns have been different than for grains. The differences, I believe, are significant in several ways. For wool, the data indicate that the level of world trade in wool in the mid-1970s was not markedly higher than prior to World War II or in the immediate postwar period. Indeed, it appears there have been periods during the 1970s in which the average level of world trade was lower than it was during the late 1930s. Not only has world wool trade not expanded, there has not been a sharp change in the patterns of world trade. Prior to World War II the trade was dominated by the developed market economies both on the export and import side. This pattern has continued, the only change has been a decline in developing country exports and their share of world trade; therefore, again the developed market economies now provide an increasing percentage of world exports (about 90%). The wool imports of both the developing market economies and the centrally planned economies appear to be rising in a somewhat irregular pattern while the import share of the developed market economies is trending downward.

World cotton trade shows many similarities with world wool trade and some dissimilarities. As in the case of wool, world cotton trade has not expanded rapidly since World War II as have grains and soybeans. Indeed, the level of trade in the 1970s was not markedly higher than the level achieved in 1960. There have, however, been some significant shifts in the trade patterns for cotton.

Cotton is one agricultural commodity where the advanced market economies have steadily and consistently lost export market shares, mostly to the centrally planned economies. The developing countries, which still provide slightly more than half of the world cotton exports, have maintained their market share at the same levels they enjoyed immediately prior to and after World War II.

There also have been significant shifts in world imports of cotton. Whereas developed market economies constituted more than three-quarters of import markets during the late 1930s through 1950, they now import only half of the world's cotton. At the same time, the developing market economies have increased their cotton imports to nearly a quarter of all the cotton traded at the present time. Centrally planned economies have now increased their import share to more than a quarter of all world trade. Thus, for cotton we find a situation where both the export and import shares of the advanced market economies in world trade have declined mostly because of the export expansion of centrally planned economies and the imports of both the developing countries and centrally planned economies.

Meat and Animal Products

Trade in meat follows the pattern of the other foodstuffs. It has expanded rapidly since just after World War II and especially so since 1960, but the rate is slower than for grains or soybeans. As in other foodstuffs, however, it is the expansion of exports from developed market economies that has been most rapid, while developing countries and centrally planned economy exporters have lost export market shares.

One would expect the meat imports would go in large part to developed market economies, and this is the case. It is worth noting, however, that the growth rate in meat imports is much faster in both developing and centrally planned economies. The two groups now import about one-fifth of meat traded on world markets.

Sugar

Finally, let me summarize the trends in world sugar trade. Here again is a commodity that did not experience a substantial expansion in world trade between the late 1930s and the mid-1950s. Since that time, however, there has been a slow but steady expansion in world trade. By the late 1970s, world trade in sugar

was 50% higher than it was two decades earlier. Again, there has been a substantial shift in both the sources of exports and imports. Here again the advanced market economies have increased their share in world export markets. The developing market economies, which have always dominated sugar exports, have experienced a decline in the world export market share, while the centrally planned economies appear to have maintained an irregular but approximately stable share of world trade over a long period of time.

World sugar imports also have shifted. Between the late 1930s and 1950, the developed market economies imported 80% of the raw sugar traded. This share has now fallen to only slightly more than half of all imports. The share imported by developing market economies has grown moderately but not significantly and still fluctuates around one-fifth of world sugar imports. The major change has been in the centrally planned economies that have rapidly increased their sugar imports over the last two decades.

Can one generalize from this brief review of commodity trade patterns? I believe that some generalization can be made and that certain implications can be drawn.

First, the major growth in agricultural commodity trade has occurred in basic foodstuffs and the growth rates have been highest for products associated with personal income growth, i.e., coarse grains and soybeans. The growth rate for products for which there are close substitutes, namely fibers, has shown modest or no growth in trade.

Second, with the exception of cotton, the export shares of the developing countries have declined and those of the developed market economies have risen.

Third, with the exception of wool, the developing countries and/or the centrally planned economies are becoming increasingly important importers. In the case of wheat, these two groups of countries account for a combined total of three-fourths of the imports and for about half of world imports of cotton and sugar. In coarse grains, these two groups of countries account for 40% of all imports and for a fifth of all world soybean imports.

Future World Patterns of Trade

Are the patterns of trade of the past two decades likely to continue? My view is that they are. Among the reasons I would cite is that the bulk of the world's population increase is and will be in the developing countries and centrally planned economies. Second, in those countries increased income is likely to be translated into increased consumption of grains, soybeans, sugar, and meat and poultry products. Finally, for a variety of reasons including natural resource endowments, structure, and climate, it appears that domestic production of many of these commodities is unlikely to expand sufficiently to meet the internal needs of the developing and centrally planned countries concerned.

Trade Trends and Adjustment Mechanisms

Even though the levels of agricultural commodity exports from the developed market economies have been increasing and, thus, producers of those commodities have benefited substantially from larger markets, certain factors have not changed. What has not changed, even with modern technology, is the fact that the production of these agricultural commodities is a biological process subject to influences outside the control of man (weather) and subject to relatively inflexible lags in production response to price changes.

These adjustment problems have always been there, although they certainly are increased by the high capitalization and large cash flow requirements of large-scale modern agriculture (Hathaway).

Under a more liberal trade regime which once prevailed among the developed market economies it was possible to achieve adjustments in consumption and private stockholding as well as in production. In trade between market economies if supplies were short prices rose, consumption fell, and the adjustment was spread relatively evenly between trading nations. If supplies were large prices fell, consumption increased, and the incentive for private stockholding increased; and producer adjustment, while difficult, was achieved, often with some assistance from governments.

But what are the adjustment mechanisms in the current and future trading world for most economies? By definition, centrally planned economies have a high degree of, if not complete, government control over imports and exports, and thus, import demand is not a reflection of the variables economists nor-

mally use. In general, lower world commodity prices are not reflected in increased consumption levels nor are markedly higher world prices allowed to be reflected in reduced consumption. Thus, almost by definition this portion of the world trading economy does not allow the market mechanism to produce trade adjustment.

It also happens that the government role in imports, exports, and internal pricing of these agricultural commodities is significant in most developing countries. The reasons are somewhat different. When supplies are tight it is neither economically nor politically feasible to reduce consumption levels where large portions of the population already are at or near subsistence levels. Conversely, there are certain political and economic risks involved in expanding consumption markedly during periods of ample world supplies, given the uncertainty over the ability of the economy to sustain the higher levels in periods of shorter supplies and higher import prices. Therefore, developing countries also tend to not allow market adjustment mechanisms to function as our liberal trade adjustment theory would suggest.

In addition, a number of developed market economies have chosen for a variety of reasons to use mechanisms which isolate their consumers from world market prices and, thus, trade patterns based on market adjustment mechanisms no longer function. As a result, the countries which allow some element of market adjustment to occur are the few open market economies, and thus the burden of this adjustment falls heavily upon the producers and consumers in developed exporting countries.

If one reflects on these facts, it is easier to understand the noticeable reluctance to discuss trade liberalization in grains and a similar reluctance for consumption adjustment measures in discussions of price stabilization agreements for grains. This reluctance stems from the fact that market adjustment mechanisms are inconsistent with the economic policies concerning consumption and trade that is being followed by countries that now constitute the majority of the world's import market.

Implications of These Trends for Market Stability

What are the implications for price stability in world trade patterns when the major importing countries reduce or do not allow market adjustment and when exporting countries are primarily market economies?

The expected implication is greater price instability through time. Using a simple measure of price variability in world markets,[1] a rather steady and noticeable increase in that variability is evident. This was masked by U.S. stock accumulation policies of the 1960s, which contributed to significant price stability in world wheat and coarse grain markets as a byproduct of domestic programs.

Many have argued that the great instability in world commodity markets which we experienced in this decade was the result of an unusual run of bad weather followed by an unusual run of good weather in major producing countries. I believe this is not the underlying reason. In fact, if one examines the data, the deviation from world production trends is not markedly different in recent years than in prior periods. What is different is the increased role of trade in determining commodity prices of exporting countries and the increased quantity of that trade done in a world economy which is fully or partially isolated from traditional market adjustment mechanisms.

If my assumption that increasing instability is likely to be a characteristic in future world commodity trading patterns, the question that follows is whether the major exporters or many of the importers can cope with the potential instability. Speaking as an official in a country which is both a major exporter and a major importer, I believe the answer is no. Our producers have experienced great difficulties in this decade, and our consumers and the consumers in many importing nations have also had painful experiences.

Implications for Future Trade Policy

If my reading of past trends is correct; if my assessment that they are likely to continue accepted; and if my belief that the likelihood is low of either centrally planned or developing countries adopting adjustment mechanisms as a part of their trade policy, then we as exporters must reexamine our approach to trade and price stabilization.

The present trading and adjustment system

[1] A simple coefficient of variation was computed by five-year period and by decade for the commodities involved.

puts virtually all of the adjustment on producers in a few exporting countries during periods of large supply. Conversely, in periods of short supply the burden falls upon the consumers in a few countries, namely those that allow consumer prices to reflect world prices either through their market system or because of their inability to isolate themselves from external forces. I doubt that such a system is likely to prove sustainable for either producers or consumers for a prolonged period.

One alternative that could emerge is for current and prospective imports to embark upon a program of expensive self-sufficiency. This alternative finds many supporters in importing countries, especially in those countries which produce a significant portion of their own needs. I do not think I need to point out the implication of that course for producers in countries which are heavily dependent upon these export markets.

A second alternative, which has been pursued by the United States in recent international commodity negotiations, has been international stockpiling to reduce commodity price instability. The U.S. position has been that stockpiling costs should be shared by importing and exporting nations—a position that was viewed more favorably by others for sugar where we are a major importer than for grains where we are a major exporter.

Third, I conclude that the new realities of commodity trade lead to a need for new institutions. I am not prepared to suggest what changes are needed or possible, indeed, I believe that one cannot generalize from commodity to commodity. I believe, however, it is time to recognize that our ability to produce and export has outrun our institutional capacity to deal with the emerging trends in world commodity trade. It is time to turn our attention to building national and international efforts to cope with the new realities.

Finally, let me close by commenting on the role of economists in dealing with these problems. My view is that they have been grossly inadequate in several ways. First, they have failed to recognize the political realities of the world in which commodity trade occurs. Second, there has been little or no work done on the economics of commodity trade in a world where state trading organizations play an increasing role, especially on the buying side.

Reference

Hathaway, Dale E. *Government and Agriculture: Economic Policy in a Democratic Society.* New York: Macmillan Co., 1963.

Australia, Canada, and the United States: Trade Partners or Competitors

Alex F. McCalla, Andrew Schmitz, and Gary G. Storey

Australia, Canada, and the United States are three of the world's largest traders in temperate zone agricultural commodities. More than two-thirds of world exports of wheat, feed grains, and oilseeds originate in the three, with the United States accounting alone for nearly 40% of the wheat, 70% of the corn, and nearly 80% of the soybeans exported. In addition 25% of the world meat trade occurs among the three. Beyond these items, there is significant bilateral trade in fruits, vegetables, and assorted other products. Agricultural trade is important to the countries themselves. Agricultural exports accounted for the following percentages of total exports in 1976—Australia 43.5%, United States 20.6%, and Canada 11%. Agricultural exports are even more important to the agricultural economies of the three countries. It is not surprising, therefore, that there is an interesting set of agricultural trade issues in which all three have vital interests.

The task of this paper is to address some of these trade issues. The title of the paper suggests one approach. We have interpreted trading "partners" to mean those cases where the three countries have significant trade among themselves. In this context four such trade relationships are identified: meat exports from Australia to the United States and Canada; live animal trade; feed stuffs trade and fruit and vegetable trade all between Canada and the United States. We have interpreted "competitors" to mean those cases where the countries compete with each other for third country markets. The obvious and dominant competitive relationship is in grains. Grain exports in 1976 accounted for about 40% of Australian, 56% of Canadian, and 57% of U.S. agricultural exports.

Our justification for concentrating on this subset of issues is that they represent the majority of trade and also they are trading relationships where domestic policy choices are transmitted through the international market to other countries. Conversely, we have excluded from consideration commodities where isolationist policies are pursued, e.g., dairy, tobacco, and sugar or where none, or only one, of the countries is a major producer, e.g., fibers and tropical products.

The next section of the paper presents some data to further describe the trade in the identified products. We also note the trade restrictions that apply. In the following section we discuss the set of bilateral or trilateral trade or "partnership" issues. Section four discusses the competitive issues in the grain markets. Section five identifies some major policy issues that are involved in these relationships. As one might expect, because of the size of the United States, U.S. domestic policy actions have greater impacts on her two smaller neighbors than their policies have on the United States.

The Quantitative Nature of Trade Relationships

Table 1 presents some historical data on the trade in grains and oilseeds originating in the three countries. Third country markets are of much greater importance than intercountry trade. In the period 1975–77, wheat was the largest traded item with the three countries exporting more than two-thirds of total world exports. Trade in wheat between the three countries is small both because each country appears to have similar costs and, therefore, comparative advantage and because of trade barriers erected to protect domestic programs. The United States applies quotas as well as a 21¢ per bushel tariff. Canada requires import licenses managed by the Canadian Wheat

---

Alex F. McCalla is a professor of agricultural economics, University of California, Davis; Andrew Schmitz is a professor of agricultural and resource economics, University of California, Berkeley; and Gary G. Storey is a professor of agricultural economics at the University of Saskatchewan.

Giannini Foundation Paper No. 550.

The assistance of Nicole Ballenger in data collection is gratefully acknowledged.

Table 1. Australian, Canadian, and U.S. Grain and Oilseed Trade: 3-Year Averages 1965–67, 1975–77 (thousand metric tons)

Exporter \ Importer	To Each Other	To World	Percentage Total World	To Each Other	To World	Percentage Total World	To Each Other	To World	Percentage Total World
	Wheat and Flour			Feedgrains			Soybeans		
1965–67									
Australia	—	6,374	(11.2)	16[c]	679.8	(1.6)	—	—	(—)
Canada	31[c]	13,606	(23.8)	169[c]	1,162.8	(2.8)	—	78	(1.0)
United States	474[b]	20,972	(36.7)	1,605[ab]	21,863.0	(52.7)	752[b]	6,706	(89.0)
Total		40,952	(71.6)		23,706	(57.1)		6,784	(90.0)
World[d]		57,180	(100.0)		41,513	(100.0)		7,533	(100.0)
1975–77									
Australia	11[c]	8,086	(11.2)	—	2,287	(3.2)	—	—	(—)
Canada	23[c]	12,145	(16.9)	392[c]	4,132	(5.8)	—	24	(—)
United States	—	28,155	(39.1)	656[b]	46,512	(65.3)	404[ab]	14,675	(78.3)
Total		48,386	(67.2)		52,931	(74.3)		14,699	(78.4)
World[d]		72,026	(100.0)		71,225[f]	(100.0)		18,736	(100.0)
Value[e] ($ U.S. million)		10,763			8,929[f]			4,473	

Source: Food and Agricultural Organization of the United Nations *Trade Yearbook*, Canadian Wheat Board Annual Reports.
[a] To Australia.
[b] To Canada.
[c] To United States.
[d] Includes intra EC-9 trade.
[e] FOB.
[f] Does not include world trade in sorghum.

Board and applies a 12¢ per bushel tariff. Australia appears to prohibit grain imports. Trade in feed grains and oilseeds is likewise principally with third countries. One exception is exports of corn and soybeans by the United States to Canada. These volumes, though small relative to total U.S. exports, have significant influences on Canadian prices. Imports of these products are generally regulated by tariffs. Reductions in tariff rates were negotiated in the recent Tokyo Round. These proposed rates are shown in parentheses behind current rates. The United States applies the following rates: barley 7.5(5)¢/bushel (bu.), oats 7(0)¢/bu., corn 25(5)¢/bu., sorghum 40¢/hundredweight (cwt), soybeans $1.00(0)/cwt; Canada applies the following rates: barley 12(5)¢/bu., oats 4(0)¢/bu., corn 8(5)¢/bu., sorghum (5)¢/bu. and oilseeds free. Licenses are required on oats and barley. Australia apparently prohibits grain imports but admits oilseeds free of duty though an import permit is required.

Trade in Meat and Live Animals

Table 2 presents data on trade in beef and veal and live cattle. Trade originating in and/or between the three countries in other products—poultry, pork, and sheep meat as well as processed meat is relatively small with the three representing in all categories less than 10% of world trade. The principal trade flow of interest is the export of fresh and frozen beef from Australia to the United States and Canada. The meat trade is almost as important to Australia as is trade in wheat. Further, more than two-thirds of Australian exports go to North America. However, given relatively low trade barriers between Canada and the United States, there exists something approaching a North American meat market which transmits external impacts to both countries. There is also a significant trade between Canada and the United States in live cattle. Trade barriers in the livestock and meat trade are complicated. Again they were the subject of GATT negotiations. Both current and proposed restrictions are presented with the latter in parentheses. U.S. barriers are: live animals—1-1/2¢/pound (lb.) or 2-1/2¢ depending on weight (1¢/lb.–no quotas), beef and veal–3¢/lb. with a quota if imports exceed 7% of domestic consumption (2¢/lb.–possibly countercyclical quotas). Canada barriers are: live animals 1-1/2¢/lb. (1¢), beef and veal 3¢/

Table 2. Australian, Canadian, and U.S. Meat and Livestock Trade: Averages 1965–67, 1975–76

Importer / Exporter	Beef and Veal—Fresh and Frozen (thousand metric tons)						Live cattle (thousand head)					
	Australia	Canada	U.S.	Sum of Three	World	Sum of Three as Percentage of World	Australia	Canada	U.S.	Sum of Three	World	Sum of Three as Percentage of World
1965–67 average												
Australia	—	2.4	170.7	173.1	287.3	60	—	0	0	0	7.4	0
Canada	0	—	23.5	23.5	25.4	93	0	—	453.5	453.5	470.6	96
USA	0	2.5	—	2.5	10.5	23	0	11.7	—	11.7	48.0	24
Sum of three	0	4.9	194.2	199.1	323.2	62	0	11.7	453.5	465.2	526.0	88
World	—	6.5	333.0	339.5	1,517.6	22	0	11.9	926.5	938.4	4,336.0	22
1975–76 average												
Australia	—	37.2	307.3	344.5	483.0	71	—	0	0	0	20.9	0
Canada	0	—	27.4	27.4	29.2	94	0	—	396.0	396.0	415.0	95
USA	0	6.0	—	6.0	28.2	21	0	74.5	—	74.5	201.0	37
Sum of three	0	43.2	334.7	377.9	540.4	70	0	74.5	396.0	470.5	636.9	74
World	<1	73.3	572.7	646.0	2,491.2	26	.8	75.8	749.0	824.8	6,864.8	12

Sources: FAO, *Trade Yearbook*, 1971, 1977; USDA ERS, *U.S. Foreign Agricultural Trade Statistical Report*, 1976; Statistics Canada, *Exports and Imports; Merchandise Trade*, 1965–67, 1975–77.

lb.(2¢). However, health and sanitary restrictions may be more important than tariff barriers. Australia requires import licenses and these in conjunction with health restrictions virtually prohibit imports (Hillman).

Trade in Fruits and Vegetables

The United States is the dominant exporter of these products. In the fresh product categories—fruits, nuts, and vegetables—Canada represents a large and important U.S. market with more than one-third of U.S. exports going to that market. Exports of processed products are more diversified. Trade barriers in this trade are minimal except for low seasonal tariffs applied by Canada on competitive crops during the summer production season.

In summary, there exists a complicated trading pattern. The three countries dominate the export side of the grain market and therefore are major competitors for import markets. However, this competitiveness in third country grain markets is related to intercountry trade through U.S. exports of corn and soybeans to Canada. This trade in turn is influenced by Canadian attempts to integrate her feed grain and livestock economy into a North American market. Australia is tied into this market through substantial meat exports to the United States and Canada. In addition, meat production in Australia is partially competitive with wheat production. Thus what appear on the surface to be separate and distinct markets are in fact highly connected through trading relationships.

"Partnership" Trading Relations

In this section of the paper we introduce some of the major issues relating to intercountry trade. Each of the topics would fill an entire paper or monograph. Therefore what we present are vignettes to highlight the issues.

Meat Trade

The establishment of the European Common Market (EC) and the subsequent entry of the United Kingdom fundamentally altered the world beef market. These structural changes coupled with rising U.S. demands for ground beef shifted the axis of Australia's meat trade from Europe to North America. Australia exports about 25% of her beef production into the U.S. market. Given that the cattle cycles in North America and Australia appear now to coincide and that the U.S. market is preferred by Australia, U.S. import policy has a direct bearing on Australian farm income. Current U.S. policy is one of a quota directly tied to domestic utilization which expands and contracts in direct proportion to U.S. production. The United States is currently debating a countercyclical import policy which would expand quotas in low marketing-high price periods and contract it in low price periods. The explicit objective of such a policy would be to reduce the amplitude price changes over the cattle cycle in the U.S. market. However, it would also export instability to Australia. The policy question facing Australia is how to respond. If the Australian cattle cycle remains in phase with the United States, such a policy would increase price instability in the Australian domestic market. On the other hand, if Australia could supply the same quantity of beef over the cattle cycle, export earnings would clearly increase. The optimum policy for Australia would be to shift her cattle cycle out of phase with the U.S. cycle. The interesting conundrum for policy makers would be how to do that.

North American Trade in Livestock and Meat Products

Live cattle, beef, and veal are the most important items in U.S.-Canadian trade. Trade in pig meat and poultry is small, but moving to the advantage of the United States. Little trade in sheep meat or processed meat occurs.

Structurally, the beef cattle cycles in the United States and Canada followed very similar patterns from 1950 to 1979, except for the short period 1965–69 when Canadian commercial slaughter as well as cattle numbers on farms declined whereas there was general expansion in the United States.

The North American regional trade patterns in cattle, beef, and veal are such that Canada exports feeder cattle from Western Canada and slaughter cattle from Eastern dairy and Western beef herds to the United States. The United States in return exports finished slaughter cattle for the meat deficit Eastern Canadian market.

Traditionally, U.S.-Canadian trade in livestock and meat has been relatively free of trade barriers. In recent years, however, na-

tional policy considerations have resulted in the introduction of various intermittent trade barriers. There was an escalation in U.S.-Canadian nontariff barriers starting with the U.S. imposition of a ceiling on retail meat prices in March 1973. The lifting of the ceiling in September 1973 resulted in a flood of cattle onto both the United States and Canadian markets. The effects are different because of the relative size of markets. The United States beef industry dwarfs the Canadian industry by a ratio of approximately 10:1 which at times has resulted in disequilibrium effects and has precipitated trade retaliatory actions by Canada in recent years. For certain weeks in 1973–74, U.S. imports reached approximately 30% of total Canadian slaughter. Canada countered with higher tariffs and import surcharges.

A tendency, particularly by the Canadian government, has been to introduce health regulations on cattle and beef imports. In April 1974, Canada required import certification to prevent the importation of meat of animals that had been fed diethylstibestrol (DES). As the United States has just recently (July 1979) introduced a ban on the use of DES, Canada has lifted this requirement. Canada also requires tests for blue tongue and annaplasmosis. The United States in 1977 applied import restrictions because of brucellosis problems in Canada. In addition, both countries apply quotas on dressed beef imports.

The recently completed GATT negotiations have led to tariff concessions, resulting in cuts of 40–50% and a move to more tariff-free categories. However, in assessing impacts it is clear that tariff levels have had a minor effect on trade in comparison to U.S.-Canadian exchange rate fluctuations and the much more restrictive nontariff health regulations and import quotas. In the future it appears that trade barriers will continue to be episodic based on serious market shocks.

The North American Feed Grain Market

United States-Canadian trade in feed grains is not large in comparison to total international trade and is relatively free from trade restrictions. Traditionally Canada has been an importer of United States corn for the deficit Eastern Canadian feed grain market. U.S. corn exports to Canada average 833,000 metric tons for the 1971–76 period but have declined more recently partly as a result of increased Canadian corn production. Canada is approaching self-sufficiency in corn, as production has doubled in the last ten years (Agriculture Canada 1978b).

Canadian barley exports to the United States ranged from a high of 288,000 metric tons in 1971/72 to a low of 99,000 metric tons in 1977/78. Of this total, U.S. imports of Canadian barley for malting purposes has trended upward, representing 53% of total barley exports in 1977/78 (Canadian Wheat Board). North American trade in oats and sorghum is insignificant.

Of importance to Canada-U.S. trade relations in feed grains is (*a*) the dominant position of the United States in the international feed grains market and (*b*) the Canadian feed grain policy and market structure.

In 1948/49, prairie feed grains, oats, and barley were placed under the control of the Canadian Wheat Board (CWB). This essentially created two feed grain regions in Canada, as the CWB had monopoly control over both export and domestic sales except for feed grains sold outside regular channels on a farm-to-farm basis within each prairie province. This situation created a political backlash against the CWB in the late 1960s as surplus feed grains in the prairies depressed prairie prices, while the CWB continued to price prairie feed grains at corn competitive prices in Eastern Canada. Regional price distortions favored livestock feeding in the prairies. Eastern Canadian livestock and feed grain interests were successful in pursuading the Canadian government to introduce a new feed grains policy which came into effect 1 August 1974.

The new policy essentially provided for a dual market structure, with the CWB retaining responsibility for prairie feed grain exports and domestic nonfeed utilization. Domestic Canadian feed grains were placed back on the open market. Prairie producers now had two main marketing options: (*a*) to deliver feed grain to the CWB where the price is pooled or (*b*) to deliver to the open market where price is set daily. Farm deliveries to the CWB are restricted by quotas which are largely determined by the extent of CWB export sales. Deliveries to the open market have not been restricted by quotas, but are limited by storage capacity regulations, which have not been duly restrictive. However, starting 1 August 1979 domestic marketings will be subject to quotas.

Although the CWB cannot purchase feed grains delivered to the domestic market, it is required to be a residual supplier to the domestic market. Beginning 1 August 1976, the CWB was required by the Canadian government to offer feed grains to the domestic market on a price formula which is based on the price of U.S. corn and soymeal (49%) at Montreal.

The feed grains policy was designed to provide fair and equitable prices. These price performance objectives have not been met. A comparison of the domestic cash price of barley and the CWB formula offer price at Montreal shows wide price differences. For example, the open market corn price in the third quarter of the 1975/76 crop year was 12% above the CWB formula price while in the first quarter of the 1979/80 crop year it was 21% below the formula price. This pricing problem essentially rests with both the structure of the feed grain market as described and the export decisions of the CWB.

As a result of low wheat exports and the wheat acreage reduction program in 1971, which resulted in increased barley production, the CWB developed an aggressive barley export program. Barley exports increased from 462,000 metric tons in 1968/69 to 4,883,000 metric tons in 1971/72. This was accomplished largely by the CWB offering barley below U.S. corn prices, which it was able to do without fear of U.S. retaliation because of the small Canadian market share internationally. However, in the last several years the CWB, in attempting to maximize producer revenue from grain and oilseed sales, has decreased barley exports to allow the export of higher valued wheat, flax, and rapeseed in an industry constrained by transport capacity. This has resulted in low barley delivery quotas, a build up of farm stocks, and increased farm sales to the domestic feed grain market. Increased domestic stocks have been instrumental in forcing down the domestic cash and futures prices, thus creating the price distortions. The move to lower Canadian barley prices *vis-à-vis* corn, resulted in increased Canadian corn exports and reduced U.S. corn imports. The result has also meant an income transfer from feed grain to livestock producers. Lower Canadian feed grain prices relative to corn also would tend to offset the comparative cost advantage the United States has had in livestock feeding.

Trade in Fruits and Vegetables

Canada imports more than half of its agricultural imports from the United States. Fruits and vegetables are major items in this trade. However, the export market is of relatively minor importance to U.S. producers in many commodities. The major exception would be fresh citrus from the West and nuts such as almonds and walnuts. Given that trade barriers in these commodities are minimal, happenings in the U.S. market significantly influence Canadian markets as this market is considered as part of the U.S. fresh market. Much of the U.S. fruit exported to Canada is regulated by market orders. Market orders tend to allocate products between fresh and processed markets. Casual observation of the behavior of market orders suggests that the orders maintain relatively stable shipments to the fresh market and adjust the quantities going to the processing industry with changes in production. For example, if one looks at the utilization of California-Arizona oranges and lemons one finds very stable shipments to domestic and export fresh markets and relatively wide swings in quantities going to the processing market which are directly correlated with changes in production.

"Competitive" Trade Relationships

All three countries are major exporters of grain. In the case of wheat they are most akin to large oligopolists who must take each other's actions into account. A number of authors have attempted to describe relationships among the countries. The most recent piece by Alaouze, Watson, and Sturgess postulates a triopoly price leadership model. On the other hand the overwhelming dominance of the United States in the feed grain market probably allows Canada and Australia to behave as fringe competitors who can export all they want at prices just under those of the United States. Thus the most interesting questions seem to center around the wheat market.

The failure of the Tokyo Round to reach an International Grains Arrangement has reopened the question of price stability in international markets. It is argued by state trading exporters such as Canada and Australia that a market without some form of stabilization agreement operates to the detri-

Table 3. World Wheat Market Shares

Year	Total World Exports (mmt)	Market Shares (%)			
		Australia	Canada	U.S.	Total of Three
1965/66	62.0	9.2	23.9	37.7	70.8
1966/67	55.8	12.5	26.5	35.8	74.8
1967/68	51.2	13.7	17.4	39.5	70.6
1968/69	45.7	11.8	19.0	32.2	63.0
1969/70	50.7	14.4	17.8	32.5	64.7
1970/71	54.3	17.5	21.4	36.5	75.4
1971/72	52.5	16.6	26.1	32.2	74.9
1972/73	68.3	8.2	22.8	46.9	77.9
1973/74	63.1	8.7	18.5	49.3	76.5
1974/75	63.4	12.6	17.7	44.6	74.9
1975/76	66.5	12.2	18.2	47.4	77.8
1976/77 (prelim.)	61.8	13.6	20.9	42.7	77.2

Source: International Wheat Council, *World Wheat Statistics*, Geneva, 1978.

ment of producers and to the advantage of large exporters and multinational grain firms. To some extent they base their case on their loss of market shares in the turbulent period 1972–75. Table 3 shows the three countries' market shares from 1965 to 1977. Two things stand out clearly. First the share of the export market held by the three countries is rising, now being consistently over 75%. Second, and more interesting, is the fact that the United States share of the market rose dramatically in 1972 and has remained ten percentage points higher in the post-1975 period. This growth in U.S. shares came at the expense of both Canada and Australia. Part of this change can be explained by the dissipation of large U.S. stocks but not all. Clearly the United States emerged from a period of market instability with a larger market share.

However, some in the United States argue that U.S. farmers did not benefit. Thus Americans, such as Congressman Weaver, are supporting Canada and Australia in their call for a grain export cartel. Despite the dismissal of the notion of a cartel as impractical and unworkable by the grain trade among others, it is worthwhile to consider the question. It is well known that for a cartel to work the members must control a significant part of supply, face sloping demand functions, have barriers to entry, and not encounter importer market power. In sum, for a cartel to work it must be a sellers' market and not a buyers' market as hypothesized by Carter and Schmitz. The cartel notion is seductive in that it would allow the exporters to capture monopoly rents which are now going to importers such as the EC and Japan. But developed country importers now account for less than 20% of world wheat imports. Much more important are lesser developed countries (LDC) and centrally planned markets. While it might be argued that the demand for wheat by the USSR and China is price inelastic, it is not so clear that it is for the LDCs. If the LDC demand (now 60% of the market) is price elastic, a price increasing cartel could be counter-productive for exporters and disastrous for the LDCs. On the other hand, a feed grain cartel would seem to have greater potential for success. We are not advocating a cartel. Rather we raise the topic as a policy issue deserving of detailed policy analysis.

Partnership and Competitive Interrelationships

Our discussion has dealt with components of the trading system and therefore domestic interfaces among the three countries. Yet it is obvious that, except for the fresh fruit and vegetable trade, the markets are closely tied together. For example, a significant change in crop conditions or policy in a major grain importer has repercussions on all three countries. Large increases in Soviet grain purchases expand export demand and drive up domestic grain prices in all three countries. Rising feed grain prices reduce the profitability of cattle feeding and reduce feeder steer prices in Canada and the United States reducing the profitability of cow-calf operations. Proportionately more cows and heifers go to market

causing an increase in marketing and decreases in prices. However, as marketings rise, so does the U.S. import quota which further depresses prices. The United States reduces imports of Canadian feeder cattle but expands imports of Australian beef. Thus the USSR purchase has similar direct impacts on all three countries—namely to increase grain prices, but it has different indirect impacts on the livestock industry. U.S. and Canadian industries tend to contract while the Australian industry would tend to expand. Australia experiences a double benefit because of U.S. beef policy. Obviously, if the United States adopted a countercyclical policy, the impacts would be the opposite on Australia.

A second example of interconnectedness occurs in the grain livestock sector of North America. This is a very complicated subject upon which much has been written (*Canadian Journal of Agricultural Economics*). More recently Agriculture Canada (1978a) has developed forecasting models for a number of the components of the North American livestock economy. Thus it would be presumptuous here to delve deeply into this area. It is sufficient to note that Ottawa appears to be moving unilaterally to become more closely related to U.S. markets in feed grains and livestock. As noted earlier it is the clear objective of Canadian feed grain policy to price Canadian barley at corn competitive Chicago prices. Yet another agency of Canadian policy—the Wheat Board—by virtue of its capacity to price discriminate appears on occasion to run counter to that objective. All of this increases uncertainty in Canadian agriculture.

Concluding Comments

Our objective in this paper has been to identify some of the trade and domestic policy issues that arise because of the trade relationships between Australia, Canada and the United States. It is clear that external shocks radiate through trade relationships to all countries. The impact of these external shocks can be exacerbated or dampened by domestic policy initiatives. The importance of international markets to all three countries raises directly the question of whether cooperation in all trading relationships would be preferable to competitive or independent actions. We suggest that this type of consideration underlies Australia's and Canada's interests in cooperative arrangements in the grain-livestock sector. The United States seems less interested because the domestic market is relatively more important and because of a strong commitment to domestic income support. Further the dominant role of the private sector in U.S. agricultural trade makes the contemplation of collusive government to government action less appealing. One thing is clear however from the discussion. What the United States does in terms of domestic and/or international policy changes will have significantly greater impacts on Canada, Australia, and world markets than will changes in the other two. Further decreases in trade barriers will increase this interdependence. Thus the three countries are both partners and competitors in agricultural trade. However, it is an uneasy partnership with the dominant country not always as sensitive to the impacts on others as it might be.

References

Agriculture Canada. *Commodity Forecasting Models for Canadian Agriculture*, vol. 1, Oct. 1978, Vol. 2, Dec. 1978a, Ottawa.

Agriculture Canada. *Marketing Commentary: Grains and Oilseeds*. Ottawa, Dec. 1978b.

Alaouze, Chris M., A. S. Watson, and N. H. Sturgess. "Oligopoly Pricing in the World Wheat Market." *Amer. J. Agr. Econ.* 60(1978):173–85.

Canadian Journal of Agricultural Economics. *Canada's Feed Grain Policy*. Proceeding of 1977 Workshop of the Canadian Agricultural Economics Society, Mar. 1977.

Canadian Wheat Board. *Annual Report 1977/78*. Winnipeg, 1978.

Carter, Colin, and Andrew Schmitz. "Import Tariffs and Price Formation in the World Wheat Market." *Amer. J. Agr. Econ.* 61(1979):517–22.

Hillman, Jimmye S. *Nontariff Agricultural Trade Barriers*. Lincoln: University of Nebraska Press, 1979.

International Wheat Council. *World Wheat Statistics*. Geneva, 1978.

Statistics Canada. *Exports and Imports; Merchandise Trade*, 1965–67, 1975–77. Ottawa.

United Nations, Food and Agriculture Organization (FAO). *Trade Yearbook*. Rome, 1971, 1977.

U.S. Department of Agriculture, Economic Research Service. *U.S. Foreign Agricultural Trade Statistical Report*, 1976.

Agricultural Trade Issues among Pacific Ocean Countries: Discussion

Robert L. Thompson

Both papers presented in this session provide useful background information, and I find myself in substantial agreement with them as far as they go. However, neither paper directly addressed the theme of the session. After making several comments on the papers presented, I will comment on several important agricultural trade issues among Pacific Basin countries not treated in either paper.

Hathaway provides a useful review of trends in world agricultural trade flows and shares over the last four decades, but only tangentially discusses Pacific Basin trade issues. I concur with his identification of the developing countries and centrally planned economies as two of the most important determinants of future directions in international agricultural trade. He lists relative growth rates of population and real per capita income as important variables which drive the system. However, there are two related issues which he ignores. First is the ability to pay or balance of payments constraint of both developing countries and centrally planned economies. An important study by Valdes and Huddleston is in progress at the International Food Policy Research Institute on the likelihood of agricultural exports from developing countries being able to generate the foreign exchange to pay for their projected food import needs. We need a great deal more research on understanding the import decision-making process in both types of countries. Second, in developing countries food is a wage good which bulks large in both the consumer's market basket and in aggregate national income. Therefore, any change in food prices causes a significant change in real per capita income, thereby shifting the internal demand for food and, in turn, demand for agricultural imports. Similarly, any shock which shifts the agricultural supply schedule changes real rural incomes, shifts rural demand for food, and alters the marketed surplus beyond that expected from the supply shift alone. Hathaway is not explicit on what he assumes about the future real price of food. This will have an important effect on the future role of the developing countries in world agricultural trade.

Hathaway also emphasizes the effect of nontariff barriers to agricultural trade on the distribution of adjustments to shocks among trading countries. I concur with his statement of the problem, but would add that this is an area where we need much more research in attempting to understand and project changes in such policies and in turn their effect on agricultural trade. To be successful in projecting future agricultural trade, we must endogenize trade policy interventions in our analyses, rather than assuming an unchanging policy set. Lattimore and Zwart have made a very interesting start on this in a study of the world wheat market. Moreover, despite the fact that centrally planned economies have a high degree of government control over imports, I am not convinced that "import demand is not a reflection of the variables economists normally use." I would argue that our lack of understanding reflects inadequate research by analysts with the necessary combination of economic analysis, language skills, and institutional knowledge. We may find that import decision makers in centrally planned economies are much more rational than we presently think. Brainard's economic analysis of agricultural policy cycles in Czechoslovakia suggests that this is not as farfetched as it might sound.

In discussing the rationale for the insulating policies adopted by developing countries, Hathaway cites the political and economic risks associated with permitting consumption to increase markedly during periods of ample food supply. I feel the role of international price risk goes much deeper. Jabara and

---

Robert L. Thompson is an associate professor of agricultural economics at Purdue University, on leave with the International Economics Division; Economics, Statistics and Cooperatives Service; U.S. Department of Agriculture. Views expressed are solely those of the author and should not be interpreted as representative of the U.S. government.

Thompson recently examined the implications of international price risk for price policy in a small open economy. The results suggest that if policy makers are risk-averse and seek to maximize expected welfare of the residents of their country, the optimum policy is not to permit the world terms of trade to be reflected undistorted into the domestic economy as implied by the optimum tariff argument of conventional trade theory under perfect certainty. Rather, a higher expected level of utility is reached by distorting the domestic terms of trade away from the international terms of trade to move domestic production toward a more diversified product mix than under free trade. This provides a rationale for many developing countries' policies which artificially raise the domestic cereals price above the world price to stimulate greater food self-sufficiency, while depressing the domestic price of export crops.

Hathaway argues we should expect greater price instability through time in world markets. Therefore, our results suggest we should expect to see more trade barriers erected which insulate the internal markets from world price instability. If all developing countries do this, their collective efforts will lower the welfare of exporters and at the same time contribute to even greater world price instability. This suggests that it may be in the exporters' interest to support some scheme to achieve greater price stability in world commodity markets. I would second Hathaway's conclusion that we must find new national or international institutions to cope with the new realities of world agricultural trade.

McCalla, Schmitz, and Storey focus their discussion on three Pacific Basin countries: Australia, Canada, and the United States. They analyze whether the three are trade partners or competitors in their main traded products. With respect to competition in grains they suggest the three have "similar costs and therefore comparative advantage." Strictly speaking, comparisons of production costs, even when corrected for distortions (domestic resource costs), can say nothing about comparative advantage, but only absolute advantage. Comparative advantage is concerned with opportunity costs in terms of alternative products which can be produced with the same resources. Moreover, in discussing present and future competitiveness the authors ignore an important issue, the effects of investments in agricultural research and technological change on the locus of comparative advantage. A number of countries are expanding the resources devoted to agricultural research relative to the United States and thereby may be increasing their competitiveness in world markets.

McCalla, Schmitz, and Storey demonstrate that the U.S. market share in world grain trade increased after the period of price instability. It is important to remember that the total volume of world grain trade was growing rapidly as a number of countries' import demand schedules shifted upwards. An important question concerns the difference in the supply response possibilities of Australia, Canada, and the United States. This is related to the comparative advantage issue—both with respect to the total land available for crop production and the profitability of alternative uses for the land in grain production. That is, how do the size and shape of the production possibility surfaces differ among the three countries, and how are they changing through time? The focus of the McCalla, Schmitz, and Storey paper on market structure as a determinant of market shares clouds some of the underlying agronomic, as well as economic, bases for supply response in the respective countries. Differences in the structure of internal demand and substitution possibilities also are important here.

Two other important research issues are raised in the paper. They point out that optimum beef policy depends on whether the cattle cycles of the principal trading countries are in phase or not. A number of recent developments have been made in working out the capital-theoretic basis for livestock supply response (e.g., Jarvis). Some cross-country research applying these principles would seem to be very useful at this point. Second, the authors raise the grain export cartel issue. I would only reemphasize the need to draw upon imperfect competition theory and perhaps game theory in specifying richer models or paradigms for analyzing world grain trade among "large oligopolists who must take each others' actions into account."

There are a number of important agricultural trade issues among Pacific Basin countries which have not been brought out explicitly in either paper. The first is the future role of the People's Republic of China in world agricultural trade. The second concerns the demands by the developing countries of the region for greater food security, whether

through increased self-sufficiency, a reserve stocks scheme, or a food facility at the International Monetary Fund. A third is the issue of agricultural protectionism and adjustment possibilities, particularly in the high income countries of the region.

I will close by seconding Hathaway's call for much more research by agricultural economists to improve our understanding of the world market and its interaction with the domestic market in determining food prices and farm incomes.

References

Brainard, Lawrence J. "Policy Cycles in a Planned Economy: The Case of Czechoslovak Agricultural Policy, 1948–67." Ph.D. thesis, University of Chicago, 1971.

Jabara, Cathy L., and Robert L. Thompson. *Agricultural Comparative Advantage under International Price Uncertainty: The Case of Senegal.* Dep. Agr. Econ., Purdue University, 1979.

Jarvis, Lovell S. "Cattle as Capital Goods and Ranchers as Portfolio Managers: An Application to the Argentine Cattle Sector." *J. Polit. Econ.* 82(1974):164–71.

Lattimore, Ralph G., and Anthony C. Zwart. "Medium Term World Wheat Forecasting Model." *Commodity Forecasting Models for Canadian Agriculture,* ed., Z. A. Hassan and H. B. Huff, vol. 1, pp. 15–42. Ottawa: Agriculture Canada, 1979.

Valdes, Alberto, and Barbara Huddleston. *Potential for Agricultural Exports to Finance Increased Food Imports in Selected Developing Countries.* Occ. Pap. No. 2, International Food Policy Research Institute, 1977.

Agricultural Trade Issues among Pacific Ocean Countries: Discussion

Leo V. Mayer

Expanded international trade has become a new national priority for the United States. Agricultural trade is the national success story of this decade. And trade in grain and oilseed products is drawing world leaders closer together. These are among the messages that Hathaway; McCalla, Schmitz, and Storey have brought us in their formal papers.

World agricultural trade is a growth story. While our speakers have described it in very low key, almost academic terms, it certainly can be described in far more exciting terms. The growth in both quantity and dollar terms exceeds what analysts have a right to expect, given the inelastic demand for food, the role of food in the national security of nations, and the protectionistic attitude of world leaders toward agricultural markets since World War II.

Against this background, the message in the Hathaway paper showing a doubling of world wheat trade since 1960, a tripling of world coarse grain trade since 1960, "tremendous" growth in soybeans over this same period, and substantial growth in meat and animal products, is far more impressive than it appears at first glance. Nations are placing more emphasis on how their populations eat and this is adding up to more imports of agricultural products. As a major food exporting nation, this trend has redounded to our benefit, and to Canada, and Australia, as McCalla, Schmitz, and Storey indicate.

McCalla and his colleagues also indicate that many restrictions remain between nations, including those imposed by fluctuating exchange rates as well as nontariff health regulations and import quotas, and the authors imply that these restrictions continue to prevent the ideal flow of trade between nations. Unfortunately, this "ideal flow of trade" is largely left out of this discussion. Were it to have been included, it would have been less descriptive, less explanatory of past trends, and more prescriptive and indicative of future trends. In this view, we might ask more nearly, "what should the future hold for agricultural exports rather than what has it held in the past?"

This point is on my mind partly as a result of my participation in the latest round of trade negotiations. Trade negotiations by their very nature focus attention on those commodities which each nation wants to export more of in the future. Obviously, the choices of each nation have to be based on economic feasibility, political acceptability, and international negotiability. But most importantly, trade negotiations force a nation to make choices and it focuses attention on the future.

It was this decision-choice process that I found of interest in the Tokyo negotiations. The U.S. government found it necessary to establish priorities on which agricultural commodities should receive international pressure for market expansion. The resulting assessments were rough in analytical terms but meshed more with trends in food consumption than we perhaps had a right to expect.

I mention trends in food consumption because that was where my attention focused as I examined the priorities on different food commodities in the negotiations. Future trends in food consumption in other nations supposedly will have some influence on the mix of future U.S. agricultural trade. The question was, "could one find any indicators of what that mix of food products was likely to be in future years?" One helpful suggestion came to me from my former colleague Heady who some years ago suggested in writing that "history will prove that the problems of agriculture will follow a definite pattern over time and under economic development . . . (the) . . . quantities needed to prove this proposition are time and economic growth in sufficient magnitude" (Heady, p. 3).

My application of Heady's point was that economic growth is providing many of our

Leo V. Mayer is a senior specialist for agriculture for the Congressional Research Service, Library of Congress.

best overseas customers with the necessary purchasing power to test his hypothesis. Certainly, we can count on the second condition, time, being fulfilled. As these conditions are met, it seems logical that several countries may follow the United States, particularly in terms of a changing mix of food products consumed and, of necessity, of products produced or imported.

That led me to look at the change in food consumption in the United States over the last forty years. Since we are all broadly familiar with it, great detail is unnecessary. Meat and fish consumption is up more than 60%, dairy products are down slightly, flour and cereal consumption is down substantially, and other major categories are much the same after four decades. The broad trends are that protein products increase and carbohydrates decline as development proceeds. Now the question is: does the pattern of U.S. agricultural exports show any such movement?

If one goes back a quarter of a century, the picture does not really support any such trend in U.S. farm exports. Instead, farm exports have moved in the opposite direction. Meat and poultry products have declined as a percentage of farm exports (table 1) and grain and oilseed products have doubled. While the value of all farm exports have doubled several times over, the trends in commodity composition are far different than one might expect, based on any theoretical analysis of changing patterns of economic development and food consumption.

The reasons are not hard to find. Concessional sales of a significant part of our farm exports over the last quarter century are partly the cause. Under public programs, we developed "receiving stations" for U.S. farm products in the low income nations. This practice led to a large increase in shipments to Africa and Asia, for example, relative to Europe and Oceania (table 2). Partly, the different trends are due to restraints of the type McCalla and his coauthors describe which have been imposed by other developed countries. Restraints have been placed on imports of meat by Japan, the European Community, and other developed countries. So while a large part of our exports is going where economic growth has provided expanded purchasing power, proportionately, the expansion has been in other areas of the world.

In my own mind, both the trends in composition of agricultural exports and the destination of those exports raise questions that I think need to be analyzed, and I would liked to have seen our authors discuss them. Perhaps we are doing as well as is possible in terms of our agricultural exports. It is very hard to argue with success like we have experienced since 1972. On the other hand, the need for success is even greater. The U.S. balance of payments is still negative, and will probably remain so for several years. Whether we could improve

Table 1. U.S. Agricultural Export Shares By Commodity, 1955–75

Product Group	1955 (%)	1965 (%)	1975 (%)
Meat, poultry, and products	2.5	2.8	2.7
Fats and oils	5.9	3.6	1.6
Dairy products	3.5	2.1	0.6
Subtotal	11.9	8.5	4.9
Food grains and products	17.8	22.2	28.3
Feed grains and products	11.6	18.8	25.3
Oilseeds and products	10.1	14.9	20.3
Subtotal	39.5	55.9	73.9
Fruits and preparations	5.7	5.0	3.2
Vegetables, nuts, and products	3.5	3.2	3.5
Subtotal	9.2	8.2	6.7
Tobacco, unmanufactured	11.1	6.1	4.0
Cotton, raw	14.7	7.8	4.5
Hides and skins	1.9	1.7	1.9
Subtotal	37.7	15.6	10.4
Other items	11.6	11.7	4.2
Total	100.0	100.0	100.0
Value (million dollars)	3,199.1	6,228.6	21,884.1

Source: U.S. Department of Agriculture, Economic Research Service, *U.S. Foreign Agricultural Trade Statistical Report*, calendar years 1956, 1966, and 1976. Washington, D.C., June 1957, July 1967, and June 1977.

Table 2. U.S. Agricultural Export Shares by Destination, 1955–75

Destination	1955 (%)	1965 (%)	1975 (%)
North America (incl. Canada)	8.2	9.9	8.3
Latin America	14.2	8.2	10.4
Europe	51.4	41.4	35.5
USSR	—	0.5	5.2
Asia	11.1	20.1	20.7
Japan	10.6	14.1	14.1
Oceania (incl. Australia)	1.1	0.8	0.5
Africa	3.3	5.0	5.3
Total	100.0	100.0	100.0
Value (million dollars)	3,492.6	6,228.6	21,884.1

Source: U.S. Department of Agriculture, *Foreign Agricultural Trade of the United States, Fiscal Year 1955–56*, calender years 1965 and 1975. Washington, D.C., January 1957, September and June 1977.

on that situation by exporting higher valued farm products is a question that deserves more attention than we are giving it.

Thus, I conclude with several questions: Could we be even more successful if our government maintained a constant diplomatic effort at opening up overseas markets for higher valued farm products instead of the intermittent effort in trade negotiations? Would the higher demand elasticities of these types of products change the stability of agricultural trade, a factor that Hathaway feels is so important? Would expanded trade in higher valued farm goods be the best rural development program we could develop for rural America? Would it also be useful to developing countries by lowering the U.S. competition with them in producing basic farm commodities? Are we drifting into a raw-material-supplier status which has been so unbeneficial to other nations in the last few decades? These are questions that deserve attention.

References

Heady, Earl L. *Agricultural Policy under Economic Development*. Ames: Iowa State University Press, 1962.

U.S. Department of Agriculture, Economic Research Service. *Foreign Agricultural Trade of the United States, Fiscal Year 1955–56*, calendar years 1965 and 1975. Washington, D.C., Jan. 1957, Jun. and Sep. 1977.

———. *U.S. Foreign Agricultural Trade Statistical Report*, calendar years 1965 and 1975. Washington, D.C., Jun. 1957, Jul. 1967, Jun. 1977.

The Effects of Changes in Population Characteristics on U.S. Consumption of Selected Foods

Larry Salathe

Numerous changes have occurred in the characteristics of the U.S. population since 1960. A steady decline in the birth rate has resulted in a decrease in average household size and the number of preteen children. Also, a sharp increase has occurred in the number of teenagers, young adults, and senior citizens. Other significant demographic shifts since 1960 include a decline in the proportion of the population living in rural areas, the northeast, and north central regions, and an increase in the proportion of the population consisting of nonwhite persons.

Several studies indicate that demographic factors affect food-purchasing decisions, but few studies have examined the impact of changing population characteristics on aggregate food consumption. The purpose of this paper is to explore past effects and implications of probable future changes in U.S. population characteristics on aggregate consumption of sixteen food categories. While past studies (LeBovit, Price, Schrimper, Serow) focus primarily on the changing age-sex composition of the population this paper examines, in addition, the impact of changes in racial mix, household size, and location of residence on aggregate food consumption.

Undoubtedly, statistical problems and data inadequacies have contributed to the general lack of research on the relationship between population characteristics and aggregate food consumption. Population characteristics for the most part change slowly over time, making it difficult, if not impossible, to estimate their effect on aggregate food consumption using time-series data.

Cross-section data have been widely used to estimate the impact of particular demographic factors on household food purchases. Analyses of these data suggest that household size and composition, location of residence, and race affect household food-purchasing behavior (Peterson and Buse). Detailed time-series data on household characteristics are required if results from these studies are to be useful in examining the effects of changes in demographic factors on aggregate food consumption. But population characteristics data pertain almost exclusively to individuals rather than households.

Larry Salathe is an agricultural economist with the National Economics Division, Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture.

The Data

In this study, individual food intake data were used to examine the effects of changes in population characteristics on aggregate food consumption. These data were collected as part of the 1965–66 U.S. Department of Agriculture Food Consumption Survey (USDA 1969). In the spring of 1965, food intake data were obtained for members of 6,200 households. These households constituted the basic cross-section selected for obtaining data on household food consumption. After the household and individual socioeconomic and demographic information was obtained, respondents were requested to provide information on the amounts of various foods eaten by each household member for the day preceding the interview. Food intake included food eaten both at home and away from home. The sample consisted of approximately 14,500 individual records of which 13,771 contained food intake data.

Methodology

To isolate the effect of age and sex on food intake, individual records were segmented

into twenty different age-sex groups. The average intakes of sixteen foods for these groups are presented in table 1. These averages indicate that young children consume more milk and cereal products than young adults. Teenagers consume about the same amount of fats and oils, and larger amounts of milk, soft drinks, sugar and sweets, and bakery products than adults. Except for cereal products and fruits, consumption generally declines after adults reach the age of fifty. Males consume larger amounts of all foods, with the possible exception of fruits, than females of the same age.

Age and sex may not be the only factors that affect an individual's food consumption. Race, location of residence, and other socioeconomic and demographic factors probably also influence the quantity of food consumed. Regression analysis was used to isolate the impact of these factors on food consumption. The regression model expressed the quantity of the ith food consumed by the jth person in the kth household as a linear function of the kth household's income, size, a set of dummy variables defining the region (Northeast, North Central, South, West), a set of dummy variables defining urban, rural nonfarm, or rural farm location, and a set of dummy variables defining race (white, black, other). Household size and income squared were also included as explanatory variables. Separate regression equations were estimated for each of the twenty age-sex categories resulting in 320 equations.

These equations were used to estimate the impact of changes in population characteristics on per capita consumption of the sixteen food groups since 1950. The process of estimating the effect of changes in particular demographic factors since 1950 involved a series of steps. First, Census data were used to obtain estimates of the racial, regional, and urbanization mix for each age-sex group in 1950. Also, household size and income of each age-sex group in 1965 were adjusted to reflect changes occurring between 1950 and 1965. Using these values for the independent variables and Census data on age-sex composition, per capita consumption was estimated for the sixteen food groups in 1950. After these estimates were generated, per capita consumption in subsequent years was estimated by holding all but one demographic factor constant. In these calculations, the demographic factor took on values (for each age-sex category) that reflected its actual or projected change following 1950. Finally, per capita consumption indices were computed with 1950 equal to 100. These index numbers provide an indication of the percentage change in per capita consumption resulting from changes in a particular demographic factor.[1]

In the presentation of the results, 1950 is at times not used as the base year. The impact of demographic changes for such time periods was determined by first estimating the (percentage point) change in per capita consumption during the period resulting from demographic changes. This value was then divided by the actual percentage change in per capita consumption occurring between 1950 and the new base year. For the time period 1980–90, estimated changes in per capita consumption resulting from changes in population characteristics were divided by the percentage change in actual per capita consumption between 1950 and 1978. These calculations were not performed for soft drinks and bakery products in certain time periods because of a lack of information on per capita consumption of these products.

Results

Results of the analysis reflect both positive and depressive effects of demographic change on the five areas explored.

Age-Sex Composition

The U.S. population increased about 18% between 1950–60 (table 2). During this period, the proportion of children increased considerably, reflecting the post-World War II baby boom. The number of senior citizens also increased faster than total population growth. Changes in the age-sex composition between 1950–60 were estimated to have a depressing effect on per capita consumption of all foods except milk, cereal products, fruits, and sugar and sweets (table 3).

During the 60s and 70s the birthrate slowed, resulting in a decline in the number of preteen children. But the maturing of post-World

[1] It can be shown that the effects are not independent. In other words, the change in per capita consumption resulting from changes in all demographic factors may not be equal to the sum of each individual factor's effect. To avoid this potential problem, all demographic factors were allowed to change simultaneously when calculating the total effects of demographic changes on per capita food consumption.

Table 1. Food Intake Per Day, by Age and Sex, 1965–66 Food Consumption Survey

Age-Sex Category	Milk	Cheese	Beef	Pork	Poultry	Fish	Eggs	Fats, Oils	Bakery Products	Cereal Products	Fruits	Vegetables	Sugar, Sweets	Coffee, Tea	Soft Drinks	Total Food
									Grams							
Male																
Child (<5)	592.2	2.7	25.5	29.8	10.3	3.5	23.3	12.6	72.3	47.9	161.6	89.9	31.5	4.9	69.7	1,283.6
Child (5–9)	563.5	4.2	43.6	46.3	24.9	6.9	25.6	24.3	140.5	57.9	190.9	128.7	49.8	8.9	135.8	1,604.1
Child (10–14)	577.7	6.5	54.9	57.2	28.5	9.1	28.9	31.6	177.4	63.3	220.6	153.1	57.6	18.6	207.1	1,888.7
Child (15–19)	588.7	9.9	77.7	86.2	26.8	11.1	41.2	41.6	222.5	48.8	219.4	196.9	55.5	87.2	296.7	2,220.1
Adult (20–29)	353.2	9.2	116.2	100.5	25.1	14.3	53.0	46.1	202.4	39.2	207.4	240.8	47.1	376.6	270.9	2,315.1
Adult (30–39)	243.9	12.8	103.8	91.7	39.0	13.7	55.8	41.4	200.9	43.8	195.0	206.0	41.8	581.3	149.6	2,214.4
Adult (40–49)	245.0	11.0	103.8	79.0	36.3	13.8	50.6	36.1	192.2	41.0	211.2	219.5	47.2	622.2	123.1	2,214.1
Adult (50–59)	211.3	14.2	91.4	89.6	26.1	12.0	51.0	38.6	199.4	52.6	215.5	207.7	48.9	606.3	80.3	2,110.7
Adult (60–69)	231.3	12.1	69.2	76.4	28.3	16.0	55.1	34.2	168.9	56.9	189.7	191.3	40.6	522.8	62.1	1,884.7
Adult (70+)	210.5	10.9	48.6	54.7	31.1	11.8	45.3	27.2	148.5	61.3	200.0	179.7	45.0	505.7	36.1	1,759.5
Female																
Child (<5)	548.2	3.3	23.2	25.8	13.5	3.6	23.9	11.6	71.2	43.4	156.9	86.5	31.2	4.8	72.5	1,223.4
Child (5–9)	507.1	3.7	32.5	43.0	21.9	5.8	20.2	20.2	120.9	47.1	187.0	118.6	44.4	8.0	146.2	1,471.0
Child (10–14)	472.8	4.5	45.9	48.9	20.1	8.6	24.1	24.3	147.4	46.4	225.5	138.6	49.2	20.4	181.5	1,620.4
Child (15–19)	359.3	5.9	56.9	54.9	20.1	8.2	25.7	22.4	135.9	34.6	191.3	143.7	40.1	84.0	242.5	1,578.8
Adult (20–29)	225.6	8.4	65.3	54.9	19.9	9.9	27.3	23.7	121.8	34.0	152.4	152.3	36.7	344.6	215.2	1,638.4
Adult (30–39)	167.3	11.0	54.8	51.2	21.2	11.8	27.8	21.4	124.9	29.7	163.0	145.1	32.1	581.3	125.7	1,718.3
Adult (40–49)	147.5	12.4	59.2	51.8	24.1	12.2	32.7	23.1	119.9	24.2	184.6	150.1	30.8	564.2	100.6	1,658.6
Adult (50–59)	148.6	15.1	57.2	51.5	25.7	10.3	33.4	23.9	120.1	32.4	201.0	152.9	29.8	556.6	72.6	1,659.4
Adult (60–69)	149.4	14.5	51.8	39.7	24.1	9.8	29.5	21.3	112.9	40.9	195.0	154.3	33.0	459.7	56.1	1,502.6
Adult (70+)	162.7	11.7	37.1	38.1	27.5	6.5	30.1	19.4	123.5	47.4	189.1	137.0	30.8	386.5	34.6	1,391.4

Table 2. Change in the Percentage of the U.S. Population in Various Age Categories, 1950–90

Year Interval	Total All Ages	Under 5 Years	5 to 9 Years	10 to 14 Years	15 to 19 Years	20 to 39 Years	40 to 59 Years	60 Years and Over
1950–55	9.1	13.1	25.2	21.6	3.4	−0.5	8.3	15.5
1955–60	8.9	9.6	12.3	24.1	21.8	−0.5	8.0	11.6
1960–65	7.5	−2.5	8.3	12.5	26.7	3.5	7.5	9.2
1965–70	5.4	−13.5	−2.4	9.4	13.4	11.2	3.5	10.5
1970–75	4.2	−7.4	−12.9	−2.0	8.8	15.2	0.4	10.1
1975–80[a]	4.0	0.9	−7.1	−12.8	−0.6	15.1	0.6	9.7
1980–85[a]	4.8	17.4	1.0	−6.9	−12.6	9.2	4.1	9.2
1985–90[a]	4.6	3.4	17.1	4.6	−9.8	1.0	11.3	6.0

[a] U.S. Bureau of the Census, Series II.

War II babies caused increases in the number of teenagers and young adults. The number of senior citizens also continued to increase faster than total population growth. Holding all other factors constant, changes in the age-sex composition would have produced about a 3.7% decline in per capita milk consumption between 1960 and 1975. Per capita cereal product consumption declined slightly in response to changes in age-sex composition from 1960–75, but for the remaining foods changes in the age-sex composition had a positive impact on per capita consumption. Changes in the age-sex composition during this period were estimated to result in an increase in per capita consumption of cheese, beef, pork, vegetables, and coffee and tea between 3% to 4% while per capita soft drink consumption was increased about 7%.

The Bureau of the Census projects population characteristics under alternative birthrate assumptions. Series II projections, which assume a level of fertility that closely corresponds to recent survey data on birth expectations indicates the total population will increase about 0.9% per year during the decade of the 80s. A large increase in the number of women of child-bearing age is projected to cause a substantial increase in the number of children even though the birth rate is expected to fall below current levels. The number of persons 65 years and over is projected to increase at a rate considerably above that of total population growth during the next decade. These changes in age-sex composition were estimated to have a small negative impact on per capita consumption of all food groups except milk, cheese, poultry, eggs, coffee and tea, and soft drinks. A large increase in the adult population is estimated to contribute to a rather large reduction in per capita milk consumption (2.5%) and per capita soft drink consumption (2.2%). Changes in age-sex composition between 1980 and 1990 were estimated to have a small positive impact on per capita consumption of cheese, poultry, and eggs while per capita consumption of coffee and tea was projected to increase 7.1%.

Household Size

Household size remained relatively unchanged between 1950 and 1960, declining from 3.37 to 3.33 persons. However, household size declined dramatically after 1960, reflecting the decline in the birth rate and an increase in the number of single-person households. Average household size declined to 2.89 persons in 1976. Based upon recent trends and Bureau of the Census projections, average household size will probably decline to about 2.8 persons in 1980 and to 2.6 persons in 1990.

As household size declines, per capita income increases. Thus, a decrease in household size likely will increase individual food intake. Results presented in table 3 indicate that the decline in household size during the 60s and 70s had a positive impact on per capita consumption of all food groups except cereal and bakery products, fats and oils, and coffee and tea.[2] The food group most negatively affected by the decline in household size was fats and oils (2.4% reduction in per capita consumption). Per capita consumption of cheese, beef, fish, fruits, and soft drinks were estimated to have increased 6.2%, 3.7%, 8.1%, 4.2%, and 2.4%, respectively, between 1950–80 as a result of the decline in household size. For the remaining food groups, the decline in household size had little impact on per capita consumption.

[2] The impact of changes in household size on per capita consumption were calculated by adjusting household size of each age-sex group by the percentage change in average household size occurring between 1950 and subsequent years.

Table 3. Estimated Change in Per Capita Consumption Due to Changes in Age-Sex Composition and Household Size

Demographic Factor	Milk	Cheese	Beef	Pork	Poultry	Fish	Eggs	Fats, Oils	Bakery Products	Cereal Products	Fruits	Vegetables	Sugar, Sweets	Coffee, Tea	Soft Drinks	Total Food
								(1950 = 100)								
Age-Sex Composition																
1955	101.6	98.9	97.6	98.4	99.9	98.8	99.0	99.3	99.3	100.8	100.2	98.9	100.2	97.6	97.5	99.3
1960	103.1	98.2	96.1	97.5	99.6	98.1	98.2	99.1	99.1	101.4	100.6	98.4	100.7	94.9	97.1	98.9
1965	103.4	98.3	96.4	97.8	99.8	98.7	97.9	99.7	99.8	101.5	101.3	98.9	101.3	93.5	99.4	99.2
1970	102.0	99.6	98.2	99.3	100.6	100.4	98.4	100.9	101.0	101.4	101.9	100.2	101.7	94.6	102.6	100.0
1975	99.6	101.7	100.4	100.7	101.2	101.1	99.5	101.7	101.9	101.1	101.9	101.3	101.3	97.7	104.6	100.6
1980	96.9	103.6	101.9	101.6	101.7	101.1	100.6	101.7	102.0	100.7	101.4	101.7	100.4	101.5	104.2	100.9
1985	95.6	103.9	101.7	101.1	101.9	100.8	101.0	101.0	101.2	100.5	100.8	101.4	99.5	104.0	101.6	100.6
1990	94.8	104.2	101.0	100.6	102.5	101.0	101.1	100.8	100.9	100.2	100.6	101.1	99.4	105.6	98.7	100.4
Household Size																
1960	100.1	100.4	100.3	100.0	100.1	100.5	100.0	99.9	99.9	99.8	100.3	100.0	100.0	99.9	100.2	100.0
1970	100.4	102.3	101.5	100.2	100.6	103.0	100.2	99.1	99.6	99.1	101.7	100.2	100.1	99.3	101.0	100.2
1980	101.1	106.2	103.7	100.5	101.5	108.1	100.5	97.6	99.1	97.8	104.2	100.5	100.3	98.1	102.4	100.6
1990	101.5	108.6	105.1	100.7	102.0	111.5	100.7	96.6	98.8	97.1	105.7	100.7	100.4	97.4	103.3	100.8

If household size declines from 2.8 to 2.6 persons between 1980 and 1990, it is estimated that the decline will result in less than a 1% change in per capita consumption of most foods. However, the decline could increase per capita consumption of cheese, and fruits about 2%, and fish about 4%.

Racial Mix

In 1950, whites comprised 89.5% of the population, blacks 10.0%, and other races 0.5%. Today, whites make up about 86%, blacks 12%, and other races 2%. These trends are expected to continue into the next decade. The Bureau of the Census projects that whites will comprise 85.1%, blacks 12.2%, and other races 2.7% of the population in 1990.

A recent study comparing the food purchase patterns of black and white households concludes that black households spend less on dairy products than their white counterparts (Salathe, Gallo, Boehm). However, black households were found to spend more on pork, poultry, fish, and eggs than similar white households. The study results were derived from data collected in the 1972–74 Bureau of Labor Statistics Consumer Expenditure Survey.

The individual intake data upon which this study is based indicate black individuals consume less milk, cheese, fats and oils, bakery products, vegetables, and coffee and tea than similar white individuals. In contrast, blacks were found to consume more pork, poultry, fish, cereal products, and soft drinks than whites.

Individuals in the "other" racial category were found to consume less cheese, bakery products, and vegetables, and larger amounts of poultry, eggs, and cereal products than similar white individuals. Only limited confidence can be placed in these differences because of the small number of individuals in this racial group (319) in the 1965–66 Food Consumption Survey.

Changes in the racial mix between 1950–80 were estimated to have a negative impact on per capita consumption of milk, cheese, beef, fats and oils, bakery products, vegetables, sugar and sweets, coffee and tea, and total food consumption (table 4).[3] The largest negative impact was estimated for cheese, a 1.6% decline. For the remaining foods negatively affected, changes in the racial mix were estimated to result in less than a 1% decline in per capita consumption since 1950.

Changes in the racial mix had a positive impact on per capita consumption of pork, poultry, fish, eggs, cereal products, fruits, and soft drinks. Per capita consumption of poultry and cereal products were estimated to have increased 2.5% and 3.5%, respectively, between 1950–80 because of changes in the racial mix.

Between 1980 and 1990, changes in the racial mix were estimated to change per capita consumption of most foods by less than 0.4%. The food groups for which greater impacts were estimated included coffee and tea (0.7% decline), poultry (0.5% increase), and cereal products (1.2% increase).

Regional Population Shifts

The proportion of the population residing in the northeastern and north central regions declined 13.5% and 10.2%, respectively, since 1950. The percentage of the population residing in the South remained relatively unchanged between 1950 and 1970. However, the Bureau of the Census estimates the proportion of the population living in the South will increase about 6.5% between 1970 and 1980. Since 1950, a major increase has occurred in the proportion of the population living in the West, rising from 13.4% of the total population in 1950 to an estimated 18.2% in 1980.

The results of the regression analyses suggest that individuals in the northeastern and north central regions consume less cheese, poultry, and eggs than their counterparts located in the western region. But individuals in the north central and northeastern regions generally consumed more beef, pork, fish, and soft drinks than similar individuals in the western region. Individuals located in the South generally had consumption patterns that more closely paralleled their counterparts in the north central and northeastern regions than those of individuals in the western region. Individuals located in the South were found to be the largest consumers of poultry, soft drinks, and bakery products, and the lowest consumers of milk.

Assuming that when individuals move from one region to another they develop the food

[3] The number of individuals by race in each age-sex group was obtained from Census data, and Bureau of the Census, Series II projections.

Table 4. Estimated Change in Per Capita Consumption Due to Changes in Racial Mix, Region, and Urbanization Population Shifts

Demographic Factor	Milk	Cheese	Beef	Pork	Poultry	Fish	Eggs	Fats, Oils	Bakery Products	Cereal Products	Fruits	Vegetables	Sugar, Sweets	Coffee, Tea	Soft Drinks	Total Food
									(1950 = 100)							
Racial Mix																
1960	99.8	99.6	99.9	100.2	100.6	100.2	100.2	99.8	99.8	100.9	100.0	99.8	100.0	99.8	100.0	99.9
1970	99.6	99.1	99.7	100.3	101.5	100.7	100.4	99.6	99.6	102.0	100.1	99.7	99.9	99.5	100.2	99.9
1980	99.3	98.4	99.4	100.7	102.5	101.2	100.7	99.3	99.3	103.5	100.2	99.5	99.7	99.0	100.4	99.8
1990	99.1	97.7	99.2	101.0	103.5	101.5	101.0	99.1	99.0	105.0	100.4	99.3	99.6	98.6	100.6	99.7
Region																
1960	100.4	101.1	99.8	99.1	100.4	99.4	100.2	100.8	100.0	100.0	100.0	100.2	100.3	100.0	99.4	100.1
1970	100.7	101.6	99.7	98.4	100.7	98.9	100.5	101.2	100.0	100.0	100.0	100.4	100.4	99.9	99.1	100.1
1980	100.3	101.5	99.8	97.6	101.5	98.5	101.1	101.4	100.1	100.0	99.8	100.4	100.4	99.7	99.6	100.0
1990	100.0	101.4	99.8	97.1	102.0	98.2	101.6	101.6	100.2	100.1	99.6	100.3	100.5	99.5	99.9	99.9
Urbanization																
1960	99.2	99.0	101.6	99.3	100.4	97.6	100.5	98.3	98.8	97.8	99.4	98.6	97.9	101.2	101.7	99.8
1970	99.0	98.3	101.3	99.0	100.7	96.7	100.5	97.8	98.3	97.0	99.1	98.2	97.1	101.4	102.2	99.7
1980	98.8	98.3	101.6	99.0	100.5	96.6	100.7	97.6	98.3	96.6	99.0	98.0	96.9	101.7	102.5	99.7
1990	98.7	98.3	101.3	99.1	100.3	96.7	100.8	97.4	98.4	96.3	98.9	97.8	96.7	102.0	102.8	99.7

preferences and tastes of persons within the region, these results can be used to estimate the effect of regional population shifts on food consumption. Regional population shifts were estimated to have only a minor impact on per capita consumption of most foods between 1950 and 1980.[4] Regional population shifts were estimated to result in less than a 1.0% change in per capita consumption of all foods except cheese, poultry, pork, fish, eggs, and fats and oils since 1950. Regional shifts occurring between 1950–80 were estimated to cause a 1.5% increase in per capita consumption of cheese and poultry, a 1.1% increase in per capita egg consumption, and a 1.4% increase in per capita consumption of fats and oils. Per capita consumption of pork and fish were estimated to decline by 2.4% and 1.5%, respectively, because of regional population shifts occurring since 1950.

Bureau of the Census projections suggest that the proportion of the population living in the southern and western regions will increase 4.6% and 3.8%, respectively, between 1980 and 1990. The proportion of the population living in both the northeastern and north central regions is expected to continue to decline. These regional shifts were estimated to have little impact on per capita consumption of most foods. The largest positive impact was estimated for eggs, a 0.7% increase in per capita consumption, while per capita pork consumption was estimated to drop 0.6% as a result of regional population shifts in the next decade.

Urbanization Shifts

In 1950, 64% of the population resided in urban areas, 21% in rural nonfarm areas, and 15% were living on farms. During the decades of the 50s and 60s there was a general migration of the population from rural to urban. Nearly all of this migration seems to be accounted for by a movement of persons living on farms to urban areas. In 1970, the proportion of the population living in urban locations increased to 73.5%, while the proportion of persons living on farms declined to 5.2%. But the proportion living in rural nonfarm locations remained almost constant during this period.

The shift in the proportion of the population living in urban and rural farm locations between 1950 and 1970 had a negative impact on per capita consumption of most foods.[5] Per capita consumption of cheese was estimated to decline 1.7%, fish 3.3%, fats and oils 2.2%, bakery products 1.7%, cereal products 3.0%, vegetables 1.8%, and sugar and sweets 2.9%. Per capita consumption of milk, pork, and fruits were estimated to decline about 1.0% between 1950 and 1970 because of the movement of persons from rural to urban locations. In contrast, these movements had a positive impact on per capita consumption of beef, poultry, eggs, coffee and tea, and soft drinks.

The Bureau of the Census estimates that since 1970 the proportion of the population living in urban locations has declined slightly. Also, the proportion of the population living on farms continued to fall but at a much slower rate than in the decade of the 60s. Based upon these trends, the proportion of the population living in urban locations was assumed to decline to 72.5% in 1980 and to 71.0% in 1990. The rural farm population was assumed to decline to 3.7% of the population in 1980 and to 2.5% in 1990. Thus, the proportion of the population living in rural nonfarm locations was projected to increase to 23.8% in 1980 and to 26.5% in 1990. To estimate the impact of these projected changes on food consumption, the urban-rural distribution of each age-sex group was adjusted by the projected percentage change in the urban-rural distribution of the total population.

For the decade of the 1980s urban-rural shifts would seem to have only a very small impact on per capita food consumption. Such shifts were estimated to cause at most a 0.5% change in per capita consumption.

Conclusions

Per capita consumption of milk, pork, eggs, and coffee and tea declined between 1965 and 1975 (table 5). Demographic changes during this period appear to explain a large portion of the decline in per capita milk consumption. But demographic factors were estimated to have a positive impact on per capita consumption of pork, eggs, and coffee and tea. Per

[4] Regional age-sex composition data were obtained from the Bureau of the Census for 1950, 1960, and 1970. The Bureau of the Census also projects total population by region for subsequent years. The impact of changes in regional population shifts on per capita consumption for these years was estimated by adjusting the regional distribution of each age-sex group by the projected change in the regional distribution of the total population.

[5] For this period, the number of individuals by urbanization in each age-sex group was obtained from Census data.

Table 5. Actual Change in Per Capita Consumption, 1965–75, and the Estimated Effects Due to Demographic Changes, 1950–75, 1965–75, and 1980–90

	Actual[a]		Effects of Demographic Changes		
Item	1950–75	1965–75	1950–75	1965–75	1980–90
			(%)		
Milk	−15	−6	−1	−4	−3
Cheese	78	36	5	4	1
Beef	77	21	4	3	—
Pork	−20	−6	−2	2	−1
Poultry	96	4	6	2	1
Fish	3	12	3	6	3
Eggs	−27	−11	2	3	3
Fats and oils	15	11	−2	—	−2
Vegetables[b]	5	5	−1	2	−1
Fruits[c]	−5	6	4	2	1
Bakery products	NA	NA	−1	1	−2
Cereal products	26	−1	−1	−1	—
Sugar, sweeteners	7	8	−2	−1	−1
Coffee, tea	−30	−16	−3	3	5
Soft drinks	NA	44	8	4	−2
Total food	−7	—	—	1	−1

Note: NA, not available; —, less than a 0.5% change.
[a] Percentage change in pounds consumed per person.
[b] Excludes tomatoes.
[c] Includes tomatoes.

capita consumption of sugar and sweeteners increased 8% between 1965 and 1975, but demographic factors were estimated to have a small negative influence on per capita consumption during this period.

Demographic changes appear to explain a large portion of the increase in per capita consumption of poultry and fish between 1965–75. However, changes in population characteristics do not appear to explain the large increases in per capita consumption of cheese, beef, fats and oils, or soft drinks.

During the period from 1950–75, demographic changes appear to explain even less of the changes that occurred in per capita consumption. Per capita consumption of milk and pork declined 15% and 20%, respectively, while per capita consumption of cheese, beef, and poultry increased 78%, 77%, and 96%, respectively. Generally, demographic changes appear to explain less than 10% of the total change in per capita consumption of these foods occurring from 1950–75.

Changes in population characteristics are projected to have a negative impact on per capita consumption of milk, pork, fats and oils, bakery products, vegetables, sugar and sweeteners, and soft drinks between 1980–90. Despite an expected increase in the number of children during the next decade, demographic changes are estimated to cause a 3% decline in per capita consumption of milk and a 2% decline in per capita soft drink consumption. Demographically related changes in the next decade were estimated to result in a 1% to 3% increase in per capita consumption of cheese, poultry, fish, eggs, and fruits and a 5% increase in per capita consumption of coffee and tea.

References

LeBovit, Corinne B. "The Impact of Some Demographic Changes on U.S. Food Consumption, 1965–75 and 1975–1990." *National Food Situation.* USDA ERS NFS-156, May 1976.

Peterson, Hans P., and Rueben C. Buse. *A Bibliography on the Theory and Research on Household Expenditures.* USDA ERS Agr. Econ. Rep. No. 293, July 1975.

Price, David W. "Unit Equivalent Scales for Specific Food Commodities." *Amer. J. Agr. Econ.* 52(1970): 224–33.

Salathe, Larry E., Anthony E. Gallo, and William T. Boehm. *The Impact of Race on Consumer Food Purchases.* USDA ESCS Rep. No. 68, Aug. 1979.

Schrimper, R. A. "Effects of Reduced Birth Rates on U.S. Milk Consumption." Paper presented at AAEA meetings, Ohio State University, Columbus, 10–13 Aug. 1975.

Serow, William J. "The Implications of Zero Growth for Agricultural Commodity Demand." *Amer. J. Agr. Econ.* 54(1972):955–63.

U.S. Department of Agriculture. *Food and Nutrient Intake of Individuals in the U.S., Spring 1965: House-*

hold Food Consumption Survey, 1965–66. Rep. No. 11, 1969.

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service. *Food Consumption, Prices, and Expenditures*. Agr. Econ. Rep. No. 138, Washington, D.C., various issues.

U.S. Department of Commerce, Bureau of the Census. *Current Population Reports: Population Characteristics*. Ser. P-20, Washington, D.C., various issues.

———. *Current Population Reports: Population Estimates and Projections*. Ser. P-25, Washington, D.C., various issues.

The Effect of Demographic Shifts and Changes in the Income Distribution on Food-Away-from-Home Expenditure

Benjamin Sexauer

The sociodemographic structure of the American population has been changing rapidly in recent years. In addition, although the income distribution based on income groupings has remained fairly constant, the distribution of income among sociodemographic subgroups of the population has almost certainly changed considerably. Little attention has been given to the possible impact of demographic shifts, and even less to that of income distribution changes, on long-run movements in consumer demand. Most research has implicitly assumed that the income distribution and sociodemographic profile of the population remain stable. Although this assumption may be acceptable for short-run analysis, their impact cannot be overlooked in a long-run context. Ignoring the possible impact of income redistribution and demographic shifts can lead to biased aggregate income and price elasticity estimates. The accuracy of long-run projections also may be affected adversely.

Expenditure on food away from home has grown rapidly and is becoming an ever larger portion of total food expenditure. Some predict that within a decade 50% of food expenditures will be on meals eaten away from home (Langway and Nicholson). Underlying this prediction is the assumption that household characteristics have a strong influence on dining out. Factors such as age, sex, education, and work status of household members are judged to have a major impact on food-away-from-home (FAFH) expenditure. For this reason, FAFH expenditure is especially relevant for analyzing the effect of demographic shifts and changes in the income distribution.

This paper proposes a novel approach to estimating the effect of disaggregate compositional changes on aggregate consumer behavior over time. Earlier contributions have been made in this area by Burk (pp. 56–60), George and King (pp. 82–86), and Kelley. Specifically, this study will attempt to quantify the degree to which aggregate expenditure on FAFH depends on the distribution of income and of households among population subgroups. The effects of population and income shifts between 1960–61 and 1973–74 among forty population subgroups on FAFH expenditure are analyzed. These subgroups were created by cross-classifying by six key sociodemographic factors. In this analysis 1973–74 is treated as the base period and the projections are made back to 1960–61.

Conceptual Approach

The conceptual approach can be presented most clearly by simplifying to a case with just two population subgroups. An Engel relationship can be specified for all households and separately for each subgroup:

$$E_T = a_T + b_T Y_T, \tag{1}$$

$$E_1 = a_1 + b_1 Y_1, \tag{2}$$

$$E_2 = a_2 + b_2 Y_2, \tag{3}$$

where E is average household expenditures on FAFH; a, the constant term; b, the marginal propensity to consume or spend; and Y, average household income. Equation (1) represents the relationship between average household income and average household expenditure for the total population, hence the subscript T, and equations (2) and (3) for two subgroups. These equations apply to a point in time. The proportion of each subgroup in the

---

Benjamin Sexauer is an associate professor in the Department of Agricultural and Applied Economics, University of Minnesota.

The author is indebted to Jitendar Mann, Terry Roe, Larry Salathe, Ronald Schrimper, and Bill Tomek for helpful comments made on earlier drafts of this paper. However, he retains sole responsibility for remaining shortcomings. Don Groover provided computational assistance for much of the early work on this project. Rueben Buse generously supplied much of the 1960–61 data needed from the tapes available at the University of Wisconsin.

population is W_1 and W_2, respectively, $W_1 + W_2 = 1$. Then, it is true that average household expenditure for the total population is equal to the weighted average of both subgroups:

$$(4) \quad E_T = W_1(a_1 + b_1Y_1) + W_2(a_2 + b_2Y_2).$$

If shifts in the subgroup proportions and incomes, the W's and Y's, occur over time, the change in E_T can be decomposed into two effects. The total differential of equation (4) is

$$(5) \quad dE_T = E_1dW_1 + E_2dW_2 + b_1W_1dY_1 + b_2W_2dY_2.$$

The first and second terms on the right hand side of the equation represent the demographic change effect due to shifts in the subgroup population proportions and the third and fourth terms, the disaggregate income change effect due to changes in subgroup incomes.

This approach will explain only a portion of the actual change in average aggregate expenditure (E_T) over time, since the effects of relative price changes are excluded. In addition, equation (5) allows for changes in the variables, but assumes the parameters remain constant. Demographic shifts are treated as a transference of the average tastes and income of one subgroup of the population for those of another subgroup. The impact of demographic shifts is an amalgam of both a taste-related and an income-related response. Differences in tastes between subgroups influence the income response parameter as well as the constant expenditure factor.

To isolate the income redistribution effect, the impact of income growth with a constant distribution must be removed from the income effect specified in equation (5). The relative distribution of income would remain unchanged if income changed by an equal percentage for each subgroup. Therefore, for the two subgroup case,

$$(6) \quad dE^*_T = W_1b_1\left(Y_1\frac{dY_T}{Y_T}\right) + W_2b_2\left(Y_2\frac{dY_T}{Y_T}\right)$$

is the effect on expenditure of an income change with the distribution held constant, where (dY_T/Y_T) is the percentage of change in income for all households. Thus $\left(Y_1\frac{dY_T}{Y_T}\right)$ and $\left(Y_2\frac{dY_T}{Y_T}\right)$ represent an equal percent change in income for the two subgroups.

The effect of income redistribution can then be isolated by subtracting (dE^*_T) from the disaggregate income change effect in equation (5). Hence,

$$(7) \quad dE^{**}_T = b_1W_1dY_1 + b_2W_2dY_2 - dE^*_T,$$

or, rearranging terms,

$$(8) \quad dE^{**}_T = W_1b_1\left(dY_1 - Y_1\frac{dY_T}{Y_T}\right) + W_2b_2\left(dY_2 - Y_2\frac{dY_T}{Y_T}\right).$$

The terms within parentheses in equation (8) represent the difference between the actual change and the equal percentage change in income for each subgroup, or the income redistribution.

For empirical application, the model for two subgroups must be converted to one involving discrete units of time and J subgroups. The change in average overall expenditure between two periods of time is,

$$(9) \quad \Delta E_T = \sum_{j=1}^{J} E_j\Delta W_j + \sum_{j=1}^{J} b_jW_j\Delta Y_j + \sum_{j=1}^{J} b_j\Delta Y_j\Delta W_j, \quad \text{and}$$

$$(10) \quad \Delta E^*_T = \sum_{j=1}^{J} b_jW_j\left(Y_j\frac{\Delta Y_T}{Y_T}\right).$$

Equation (9) is the discrete, general case analogue of equation (5) and equation (10), of equation (6). Equation (9) contains a third term which does not appear when dealing with the infinitesimally small changes implicit in equation (5).

In equation (9), the change in the population proportion for each subgroup between the two periods (ΔW_j) is multiplied by expenditure by that subgroup in the first period (E_j), then summed across all subgroups. Next, the change in income (ΔY_j) for each subgroup is multiplied by the marginal propensity to consume (b_j), weighted by the population proportion for that subgroup (W_j), and then summed across the subgroups. The third term represents a combination of demographic and income changes and probably is not very large.

To illustrate the above derivations for the discrete case, we present the following calculation for a specific subgroup where the change between two periods of time is a function of W and Y:

$$(11)\quad \Delta(W_1, Y_1) = (W_1 + \Delta W_1)(a_1 + b_1 Y_1 + b_1 \Delta Y_1) - W_1(a_1 + b_1 Y_1).$$

The term to the right of the minus sign represents the effect of subgroup (1) on aggregate expenditure (E_T) in period 1, and the term to the left of the sign the effect in period 2. The change in the population proportion between the two periods is (ΔW_1) and in income (ΔY_1). After rearranging terms,

$$(12)\quad \Delta(W_1, Y_1) = \Delta W_1(a_1 + b_1 Y_1) + b_1 W_1 \Delta Y_1 + b_1 \Delta Y_1 \Delta W_1.$$

Equation (12) specifies for a single subgroup the relationship represented in equation (9).

Data and Subgroup Specification

The data base for this study consists of the 1960–61 Bureau of Labor Statistics and U.S. Department of Agriculture (USDA) *Survey of Consumer Expenditure and Incomes* and the 1972–73 Bureau of Labor Statistics *Consumer Expenditure Survey*. The data actually used from the second survey are from the second year of the diary portion, which covered July 1973 to June 1974. The 1960–61 survey covered some 13,725 households. The 1973–74 data covered some 10,093 households after eliminating those that did not report income or for which two weeks of expenditure data were not available.[1]

Average household expenditure on FAFH in home city was \$490.83 in 1973–74. The comparable figure in 1960–61 was \$197.18, or \$360.34 in 1973–74 prices. Therefore, the change in average expenditure was \$130.49 in 1973–74 dollars (U.S. Dep. Labor). Hereafter, all 1960–61 dollar figures have been converted to their 1973–74 equivalents using the consumer price index (CPI) for FAFH or the Index for all goods in the case of income.

The different definition of away-from-home-food expenditure used in the two data sets eliminates the possibility of comparing FAFH expenditure for the population subgroups between 1960–61 and 1973–74. The diary data tape for 1973–74 confined FAFH to expenditures in the home city, including board, snacks, and nonalcoholic beverages away from home, but excluding meals accepted as part of pay. On the data tape for 1960–61 available for use in this analysis, FAFH covered home city and out of home city expenditures, plus meals as pay.

The six sociodemographic factors used to specify population subgroups were selected on the basis of cross-sectional indications of their importance and because they exhibited large relative changes in the last twenty-five years. This rationale was suggested by Agarwala and Drinkwater.

The six variables ultimately selected were household size, age, sex, and education level of the household head, urbanity, and presence of a working spouse. Each variable was placed on a binary basis: single person versus multiperson households, household head 65 years and over versus under 65, urban versus rural, head college-educated versus not, household head male versus female, wife works outside household versus not. Although more than two age and household size categories would be desirable, there was a need to limit the number of classification factors to a reasonable level. Regression analysis showed that the age and household size categorization used captured the more important effect of each, though.

Table 1 presents the regression results used to establish the importance of the sociodemographic classification factors used. A linear functional form with ordinary least squares (OLS) was used to estimate the relationship between FAFH and the sociodemographic variables. The dependent variable was annual household dollar expenditure on FAFH. Each sociodemographic variable was allowed to not only affect the constant term, but also the coefficient on income. Income was the only variable specified in a continuous form. The regression was run across the entire sample of households for 1973–74.

The regression results indicate the importance of the sociodemographic factors. Age, education, and sex have a statistically significant effect at the .05 level on the constant term. Household size, age, and urbanity each have a significant effect on the income coefficient. When the regression was calculated for married households only, the working wife coefficient was 48.24 with a t-statistic of 1.61. If the dependent variable was then specified as the proportion of total food ex-

---

[1] At the time of this analysis, the income data for households with incomes below \$2,000 and above \$35,000 were withheld. Also, if the household size was greater than six, actual size was not reported. In each situation, the mean value was utilized; \$1,001 for incomes below \$2,000, \$48,457 for income above \$35,000, and 7.93 persons for families of seven members and larger.

Table 1. Regression Results: Annual Expenditure on Food Away from Home

Explanatory Variables	Coefficients
Constant	113.65
Family size (2 & above = 1)	−20.41
	(.82)[a]
Age (65 and above = 1)	−82.60
	(3.62)
Urbanity (rural = 1)	−35.94
	(1.45)
Education (college degree = 1)	103.56
	(4.57)
Sex (male = 1)	99.41
	(3.95)
Working wife (=1)	15.82
	(.60)
Income (continuous)	.0374
	(12.72)
Income interacted with:	
Family size (2 & above = 1)	−.0115
	(4.51)
Age (65 & above = 1)	−.0078
	(3.43)
Urbanity (rural = 1)	−.0077
	(4.05)
Education (college degree = 1)	−.0023
	(1.61)
Sex (male = 1)	.0015
	(.54)
Working wife (=1)	.0018
	(1.10)
R^2	.195
Adjusted R^2	.194
Standard error	581.95
F-statistic	191.48

[a] t-statistic in parentheses.

penditure spent away from home, the working wife coefficient was .0346 with a t-statistic of 4.02.

The other reason for selecting these six sociodemographic factors is that the U.S. population underwent major shifts in relation to each during the past twenty-five years. The largest relative change was in regard to college education. The portion of the population twenty-five and over with a college education changed from 6.0% in 1950 to 13.9% in 1975, a change of 132%. The smallest shift was in the relative size of the elderly in the population, but there was over a 30% change between 1950 and 1975 even for that factor, from 7.8% to 10.3%. Each of the sociodemographic factors used, therefore, met the twin criteria of having a significant influence on FAFH expenditure and showing a large relative change over time.

Cross-classification by six binary factors yields sixty-four groupings, except if certain of the categories exclude other possibilities. By definition, neither a one-person nor a female-headed household can have a working wife. The forty population subgroups specified are enumerated in table 2. For example, subgroup (1) is composed of urban, not college-educated, under age 65, male-headed, multiperson, wife not working households. Subgroup (40) includes rural, college-educated, over age 65, female-headed, one person households.

There are substantial differences in spending on FAFH among the forty population subgroups. These differences are perhaps most striking when FAFH expenditure is given as a proportion of total food expenditure. Column (1) gives the percentage of total food expenditure that was away from home in 1973–74 for each subgroup. The highest figure was 56% for subgroup (13), urban, college-educated, under age 65, male-headed, one person households. The lowest was 6% for subgroups (29) and (30), rural, less than college-educated, over age 65, female-headed households. The average for all households was 25%. Column (2) presents a similar figure for 1960–61. However, because the definition of FAFH was different in the two surveys, columns (1) and (2) are not comparable. Subgroups (37), (38), and (39) were excluded in 1973–74 because the number of observations was so small, at three, zero, and one, respectively.

Empirical Results

The Effect of Demographic Shifts

The impact of demographic changes depends on both the magnitude of the population shifts and the degree of dissimilarity in disaggregate behavior. During the thirteen-year period analyzed in this study, there were substantial shifts among the forty population subgroups specified in table 2. Column (3) gives the percentage of the total sample population in each subgroup in 1973–74. Column (4) gives the percent figure for 1960–61.[2] One of the more substantial population movements occurred for subgroup (21), rural, less than college-educated, under 65, male-headed, multiperson households with the wife not working, which

[2] The surveys were designed to be representative samples of the U.S. population and some preliminary work indicated that households with various characteristics were represented in the right proportion. However, there is no guarantee that specific subgroups used here may not have been under or over sampled to some degree in either survey.

Table 2. Sociodemographic Subgroup Statistics

	Rural	College Degree	Age 65 & Over	Female Head	One Person Household	Working Wife	(1) FAFH/TFE (%) 73–74[b]	(2) FAFH/TFE (%) 60–61[b]	(3) % of 73–74 Population
Subgroups[a]									
1.							21	15	19.11
2.						*	28	21	19.87
3.					*		52	58	5.14
4.				*			20	18	6.77
5.				*	*		32	34	5.65
6.			*				13	9	5.10
7.			*			*	17	14	1.18
8.			*		*		25	41	1.45
9.			*	*			15	14	.85
10.			*	*	*		15	12	5.08
11.		*					27	20	4.59
12.		*				*	35	25	4.65
13.		*			*		56	63	1.47
14.		*		*			28	18	.51
15.		*		*	*		39	36	1.14
16.		*	*				24	12	.50
17.		*	*			*	18	16	.17
18.		*	*		*		50	37	.18
19.		*	*	*			18	15	.06

20.		*	*	*	*		26	17	.40
21.	*						16	13	4.52
22.	*					*	23	19	4.36
23.	*				*		35	40	.54
24.	*			*			13	16	.88
25.	*			*	*		23	23	.63
26.	*		*				8	6	1.56
27.	*		*			*	8	9	.27
28.	*		*		*		9	18	.46
29.	*		*	*			6	4	.21
30.	*		*	*	*		6	6	1.15
31.	*	*					27	14	.54
32.	*	*				*	25	17	.54
33.	*	*			*		52	34	.09
34.	*	*		*			30	19	.04
35.	*	*		*	*		44	28	.14
36.	*	*	*				19	5	.10
37.	*	*	*			*	—[c]	14	.03
38.	*	*	*		*		—	42	0
39.	*	*	*	*			—	6	.01
40.	*	*	*	*	*		18	21	.10
Total							25	18	100

[a] Marked (*) if yes, blank if no.
[b] TFE = total food expenditure. The 1960–61 and 1973–74 figures are not comparable, since they are based on a different definition of FAFH.
[c] Not calculated due to sample size.
[d] t-statistics are given in parentheses.

Table 2. Continued

	(4) % of 60–61 Population	(5) FAFH $ Expenditure (73–74)	(6) No. of Observations (73–74)	(7) *mpc*'s[d] (subgroup reg.)	(8) *mpc*'s (Table 1 reg.)	(9) 73–74 Income $	(10) 60–61 Income (73–74 $'s)	(11) Change in Income $ (60–61 to 73–74)
Subgroups[a]								
1.	22.14	519	1,929	.0259(13.01)	.0259	12,215	11,290	925
2.	16.72	662	2,005	.0280(13.09)	.0277	15,213	12,579	2,634
3.	2.12	705	519	.0522(9.52)	.0374	7,711	7,199	512
4.	4.41	334	683	.0360(11.45)	.0259	6,610	7,208	−598
5.	3.74	278	570	.0327(9.16)	.0374	5,049	5,247	−198
6.	4.90	250	515	.0250(6.42)	.0181	7,063	7,300	−237
7.	.97	354	119	.0205(4.37)	.0199	11,245	8,452	2,793
8.	.87	311	146	.0630(2.86)	.0296	3,334	3,491	−157
9.	.92	315	86	.0467(3.70)	.0181	6,573	7,741	−1,168
10.	3.36	130	513	.0123(3.12)	.0296	3,196	3,252	−56
11.	4.37	787	463	.0258(8.78)	.0236	20,824	19,352	1,472
12.	2.59	880	469	.0298(9.06)	.0254	20,819	17,428	3,391
13.	.43	758	148	.0238(3.59)	.0351	11,289	11,470	−181
14.	.35	526	51	.0187(2.80)	.0236	14,225	13,267	958
15.	.57	305	115	.0009(.13)	.0351	8,501	10,448	−1,947
16.	.36	593	50	.0059(.63)	.0158	14,796	21,798	−7,002
17.	.09	412	17	—	.0176	20,974	14,769	6,205

18.	.06	809	18	—	.0273	13,533	11,339	2,194
19.	.07	812	6	—	.0158	13,053	8,941	4,112
20.	.24	218	40	.0169(3.11)	.0273	8,965	6,370	2,595
21.	14.51	334	456	.0203(5.75)	.0182	9,826	8,282	1,544
22.	6.41	481	440	.0166(4.84)	.0200	12,598	9,531	3,067
23.	.63	475	55	.0919(4.05)	.0297	5,993	3,797	2,196
24.	.85	200	89	.0180(3.80)	.0182	6,342	5,589	753
25.	.49	140	64	.0339(4.54)	.0297	3,901	3,013	888
26.	3.74	144	157	.0204(4.20)	.0104	5,824	5,292	532
27.	.56	134	27	.0362(5.42)	.0122	7,458	5,427	2,031
28.	.54	63	46	.0134(1.01)	.0219	2,623	2,797	−174
29.	.37	77	21	.0119(2.56)	.0104	6,482	4,273	2,209
30.	1.04	56	116	.0087(1.18)	.0219	2,405	2,507	−102
31.	.87	663	54	.0249(4.09)	.0159	20,351	15,473	4,878
32.	.51	625	55	.0211(3.26)	.0177	20,574	14,380	6,194
33.	.031	533	9	—	.0274	19,139	7,899	11,240
34.	.05	718	4	—	.0159	9,829	8,166	1,663
35.	.05	379	14	—	.0274	6,638	6,709	−71
36.	.09	561	10	—	.0081	9,871	10,204	−333
37.	.02	—	3	—	.0099	—[c]	7,881	—
38.	.03	—	0	—	.0196	—	4,419	—
39.	.01	—	1	—	.0081	—	3,876	—
40.	.04	120	10	—	.0196	4,774	4,580	194
Total	100	491	10,093			11,225	9,837	1,388

decreased from 14.51% of the population in 1960–61 to 4.52% in 1973–74. Subgroup (3), on the other hand, increased from 2.12% to 5.14%.

Column (5) gives the average dollar expenditure on FAFH for each subgroup in 1973–74. The largest figure was $880 per year by subgroup (12), composed of urban, college-educated, under age 65, male-headed, multiperson housholds with the wife working. The lowest annual expenditure was $56 by subgroup (30), rural, less than college-educated, over age 65, female-headed, one person households.

Based on equation (9), the effect of demographic shifts was determined by subtracting the population figures in column (3) from those in column (4), dividing the result by 100, then multiplying by the FAFH figures in column (5) and summing over the subgroups. The projected change in household expenditure on FAFH was $29.10 going from 1973–74 back to 1960–61. Demographic shifts among the forty subgroups specified could therefore account for 22.3% of the $130.49 observed change in average household expenditure over the period.[3]

The Effect of Income Distribution Changes

The effect of income redistribution depends on both the magnitude of the changes in its distribution and the dissimilarities in the FAFH-income relationship among demographic subgroups. To derive the disaggregate income effect in equation (9), a marginal propensity to consume (*mpc*) for FAFH was needed for each subgroup. These subgroup specific *mpc*'s were derived two ways. First, regressions were estimated for 1973–74 for each subgroup with at least twenty observations. Second, a *mpc* was calculated for each of the forty subgroups from the regression results in table 1.

The first approach yielded the *mpc*'s shown in column (7) of table 2. For the twenty-nine subgroups with more than twenty observations, a linear OLS regression was run with income as an explanatory variable. Family size was also included as a variable for the subgroups composed of multiperson households. The *t*-statistics are given in parentheses next to the parameter estimates. In cases where the *t*-statistic indicated a lack of statistical significance at the .05 level, the *mpc* was assumed equal to zero in further calculations. For the nine subgroups with less than twenty but more than zero observations, the average *mpc* for all households of .0261 was used in the calculations. This average *mpc* value was estimated in a linear regression run over the entire sample for 1973–74 with the six sociodemographic variables affecting the constant, but not the income coefficient.

The second approach produced the *mpc*'s presented in column (8). Based on the regression results shown in table 1, subgroup specific income coefficients can be derived using the income coefficient and sociodemographic variable interaction terms. The income coefficient presented in table 1 of .0374 is representative of the *mpc* for an urban, less than college-educated, under age 65, female-headed, one-person household. Any interaction effect larger than its standard error was utilized in deriving subgroup specific income coefficients. The income interaction coefficient for sex had a *t*-statistic of less than one, so the *mpc*'s for subgroups differentiated only by the sex of the household head were assumed to be equal.

The largest statistically significant *mpc* in column (7) is .0919 for subgroup (23), rural, less than college-educated, under age 65, male-headed, one-person households. On the other hand, the income coefficient is not statistically different from zero for subgroups (15), (16), or (28). In column (8) the *mpc*'s range from .0374 to .0081. A $1.00 increase in income increases FAFH expenditure by $.037 for subgroups (3) and (5), urban, less than college-educated, under age 65, both male- and female-headed, one-person households. The smallest *mpc* is for subgroups (36) and (39), rural, college-educated, over 65, both male- and female-headed, multiperson households, with the wife not working if the head is male. The differences between the *mpc* estimates in column (7) and (8), where they exist, may be partially due to the different specification for household size in the two approaches. The binary regression simply specified household size as one-person or multiperson. On the other hand, the subgroup specific regressions for multiperson households contained a household size variable.

Column (9) gives the mean household total money income before taxes for the demographic subgroups in 1973–74. Column (10) presents the 1960–61 income figure in 1973–74 dollars. Column (11) calculates the change in

[3] Some thought was given to correcting for family size changes on a subgroup basis. However, the family size changes were small enough that their impact on a subgroup basis could be ignored.

income between 1960–61 and 1973–74. The larger increases are recorded among certain of the rural households. These results should not be surprising since 1973 and 1974 were the two best years in history for U.S. farm income. Some thirteen subgroups actually suffered a decline in real income between the two surveys. These results may be partially explained by the downturn of the overall economy during 1974 preceding the last recession. However, certain of the income changes could possibly reflect an abnormality in the subgroup samples for one or both of the surveys. In analyzing subgroups, the sample size was small enough in many cases that a household with an abnormally high income could have a large influence on the mean.[4]

From equation (9), the disaggregate income change effect was determined by multiplying the income coefficients in column (7) or (8) by the subgroup income changes in column (11). This result was then multiplied by the 1973–74 population percentage weights in column (3) divided by 100. Based on the *mpc*'s in column (7), calculated by subgroup specific regressions, the projected change of expenditure on FAFH was $32.69 between 1973–74 and 1960–61. Based on the *mpc*'s in column (8), derived from the table 1 regression results, the projected change was $29.62 due to disaggregate income changes. The sign is negative in both cases going from 1973–74 back to 1960–61.

The effect of income distribution changes can be isolated by subtracting equation (10) from these results. The average percent change in real income across all households was 12.37%, $1,388 divided by $11,225. Based on equation (10), the 1973–74 subgroup incomes in column (9) were each thus multiplied by .1237. The resulting change in income was multiplied by the income coefficients in column (7) or (8) and the 1973–74 population weights in column (3) were applied.

A 12.37% change in income with a constant distribution produces a change in FAFH expenditure of $37.57 using the *mpc*'s in column (7) and $35.62 based on those in column (8). Subtracting $37.57 from $32.69 yields −$4.88, or $35.62 from $29.62 yields −$6.00. The negative sign means that income distribution changes caused a change in FAFH expenditure opposite in direction from that which occurred. If the distribution of income were the only factor changed, FAFH expenditure would have increased going from 1973–74 to 1960–61 or decreased going from 1960–61 to 1973–74.

The underlying explanation is that some of larger income increases between 1960–61 and 1973–74 occurred for subgroups with below average *mpc*'s for FAFH. An example is the large increases for many rural households due to high farm incomes during the latter survey. On the other hand, some of the smaller increases in real income, even negative in some cases, were for subgroups with higher than average *mpc*'s. One problem in this analysis may be the use of current income, rather than some measure of permanent income, particularly in the case of households with volatile incomes such as farmers.[5]

The multiplicative income and demographic change factor, the third term on the right side of equation (9), produces a change of −$.73 based on the *mpc*'s in column (7), and of −$1.09 based on the *mpc*'s in column (8).

Conclusions

These results may partially explain the lack of consistency among aggregate parameter estimates from cross-sectional data sets collected in different years. Harmston and Hino in analyzing two cross-sectional data sets separated by ten years found a lack of consistency in the aggregate income elasticity estimates. Such a change could be explained at least partly by population and income shifts among subgroups with different coefficients. Agarwala and Drinkwater pursued this line of reasoning for the aggregate consumption function. Carrying this idea further, some of the behavior which economists normally attribute to taste changes can actually be quantified as being a result of compositional shifts.

Ignoring demographic and income distribution shift effects, when they are significant, will lead to specification bias. This left-out variable bias may affect the income and price effect estimates in a time-series regression analysis. As a corollary, long-run projections made on the basis of income and price elasticities so estimated will yield inaccurate pre-

[4] The problem may arise partly because of the nonreporting of incomes over $35,000 in the 1973–74 data, which forced the use of an average income over that level.

[5] The disaggregate income change effect of equation (11) also can be compared to the aggregate income effect, which is typically calculated. Based on the *mpc* for all households in 1973–74 of .0261 and the average change in income of $1,388 in 1973–74 dollars, the projected change in expenditure was $36.23.

dictions, when substantial changes do occur in the demographic profile and/or income distribution.

A possible approach to correcting this misspecification problem might be to use the cross-sectional estimates of the effect of demographic and income distribution changes as extraneous information to obtain a "corrected" time-series data set. The use of cross-sectionally generated estimates as extraneous information in a time-series regression analysis was first pursued by Tobin. This approach would also allow the residual movement in FAFH expenditure, not accounted for by demographic or income distribution changes, to be explained at least partially by changes in aggregate income and relative prices. The simplest correction would be to treat changes in the income distribution and demographic profile as a trend factor. The annual change in FAFH due to these factors could be converted to the correct constant dollar base, placed on a per capita basis, multiplied by the trend value for each year, and subtracted from the annual FAFH time series. The "corrected or residual" FAFH series could then be considered a function of aggregate per capita income and prices. The original intention was to carry out this procedure. However, the severe collinearity between the time-series price and income series precluded this.

Two assumptions are essential to the approach employed in this study. First, the stability over time of the disaggregated parameters is assumed. The *mpc*'s estimated with the 1973–74 data for the sociodemographic subgroups are applied to the 1960–61 period. A check on the consistency of the disaggregated parameter estimates would have been highly desirable. This check could not be made because of the definitional difference in FAFH in the 1960–61 and 1973–74 data available for this research.

Second, but equally as critical, this analysis relies on drawing inferences concerned with changes over time from cross-sectional estimates. A considerable literature exists on this topic (Kuh, Kuh and Meyer, Maddala; Tobin). Kuh argues for caution in applying cross-sectional estimates to time-series processes. Those less skeptical would probably be willing to accept cross-sectional estimates as approximately equivalent to long-run time-series parameters (George and King, p. 68; Kuh and Meyer). Moreover, a long history exists in demand analysis of using cross-sectional data to generate estimates that are primarily applicable to a time-series context, such as the work of Frisch or Pinstrup-Andersen.

A further limitation of this approach is that the sample size for many of the subgroups is extremely small, which affects the reliability of the estimates. For example, the confidence level at the .90 level for the mean FAFH expenditure for all households of $491 is between $480 and $502. For subgroup (22) with 440 observations, the 90% confidence interval is between $441 and $521, with the mean at $481. For subgroup (26) with 157 observations, the mean is $144, and the confidence interval is $106 to $182. The confidence intervals about the estimated values for smaller subgroups became extremely wide. However, there is a mitigating factor. Because the effect of a subgroup on aggregate FAFH expenditure is in relation to its relative size in the population, the possibly less accurate estimates have a minimal influence on the results.

In summary, the limited information content of the data always has been a serious restriction in time-series related analyses. Problems of multicollinearity are prevalent and only aggregate behavior can be studied. On the other hand, large cross-sectional data sets are a rich information source, but most of the practical concerns pertain to time-series processes. The use of cross-sectional information for time-series inferences allows the effect of disaggregate compositional changes on aggregate behavior over time to be analyzed.

Demographic and income distribution shifts can have a significant effect on long-run changes in consumer demand. This analysis suggests that a major portion, 22.3%, of the observed change in average aggregate expenditure on FAFH might be explained by demographic shifts. The suggested effect of income distribution changes is small, but counter to the observed movement of FAFH, interestingly. Moreover, this study has presented a methodology which can be applied to any commodity. Aggregate demand analyses can conceal a considerable diversity in consumer behavior among subgroups of the population. Disaggregate compositional changes may, in turn, have a significant impact over time on average aggregate behavior. In addition, questions concerned with specific subgroups of the population and distributional impacts are becoming increasingly important themselves in our society.

References

Agarwala, R., and J. Drinkwater. "Consumption Functions with Shifting Parameters Due to Socio-Economic Factors." *Rev. Econ. and Statist.* 54(1972):89–96.

Burk, Marguerite C. "Measures and Procedures for Analysis of U.S. Food Consumption." USDA Agr. Handbook 206, June 1961.

Frisch, Ragnar. "A Complete Scheme for Computing All Direct and Cross Demand Elasticities in a Model with Many Sectors." *Econometrica* 27(1959):177–96.

George, P. S., and G. A. King. "Consumer Demand for Food Commodities in the United States with Projections for 1980." Giannini Foundation Monograph No. 26, University of California, Berkeley, Mar. 1971.

Harmston, Floyd, and Hiroyuki Hino. "An Intertemporal Analysis of the Nature of Demand for Food Products." *Amer. J. Agr. Econ.* 52(1970):381–86.

Kelley, Allen C. "Demand Patterns, Demographic Change, and Economic Growth." *Quart. J. Econ.* 83(1969):110–26.

Kuh, Edwin. "The Validity of Cross-Sectionally Estimated Behavior Equations in Time Series Applications." *Econometrica* 27(1959):197–214.

Kuh, Edwin, and John R. Meyer. "How Extraneous are Extraneous Estimates?" *Rev. Econ. and Statist.* 39(1957):380–93.

Langway, Lynn, and Tom Nicholson. "America: Out to Eat." *Newsweek,* 3 Oct. 1977, pp. 86–90.

Maddala, G. S. "The Likelihood Approach to Pooling Cross-Section and Time Series Data." *Econometrica* 39(1971):939–53.

Pinstrup-Andersen, Per, and Elizabeth Caicedo. "The Potential Impact of Changes in the Income Distribution on Food Demand and Human Nutrition." *Amer. J. Agr. Econ.* 60(1978):402–15.

Tobin, J. "A Statistical Demand Function for Food in the U.S.A." *J. Royal Statist. Soc.* Ser. A, 113, part 2(1950):113–41.

U.S. Department of Labor, Bureau of Labor Statistics. *Consumer Expenditure and Income, 1960–61,* Supp. 3, part A to BLS Rep. No. 237-93, USDA Rep. CES 45, Washington, D.C., May 1966.

Demographic Change and the Demand for Food: Discussion

R. A. Schrimper

Salathe's and Sexauer's papers report substantial effects of demographic changes on food consumption in recent years even though some of the unexplained residuals are fairly large. Explanations of 50%–70% of actual changes for some of Salathe's categories and 22.3% in Sexauer's analysis are impressive. Although the latter type of comparisons are very natural, they can be misleading when various factors influencing quantities and expenditures for food have offsetting effects. In such circumstances, it is conceivable that observed changes in average consumption or expenditures per capita, or per household, actually can be less than some of the individual components. Hence, a more meaningful comparison might be made by noting the relative magnitude of individual components as in the case of Sexauer's analysis where the effect of demographic shifts was approximately the same size as the aggregate income effect regardless of which set of marginal propensities to consume was used.[1] Similarly, comparison of the magnitudes of various factors analyzed by Salathe may be more meaningful than comparisons to observed changes in per capita consumption.

In addition to empirical estimation of the extent to which changes in various population characteristics affect average food consumption or expenditures, the papers raise some interesting methodological issues. The studies complement each other by illustrating how an identical conceptual relationship can be implemented in different ways with different types of data to examine similar questions. The basic relationship underlying each of the studies is that national average consumption or expenditure per capita, or per household, is a weighted sum of population subgroup averages. The analyses focus on measuring changes in national per capita or per household averages resulting from changing distributions of the population among subgroups and the effect of adjustments in subgroup averages. Interesting questions arise, however, as to how subgroups of the population should be defined, and should a given variable be used to define more detailed subgroups of the population or should its effects be handled by adjusting subgroup or cell averages? Salathe chose to use only age and sex characteristics to subdivide the population into subgroups with the effects of other variables evaluated through modification of subgroup averages. On the other hand, Sexauer used six factors to specify population subgroups and considered income and family size as the only characteristics affecting individual cell means over time. These contrasts in methodology raise a question. Is there some criterion to help decide whether to use a given variable to define additional subgroups or to handle its effects by adjusting group averages?

Another interesting contrast between the two studies is in the specification of variables used to define subgroups or adjust cell means. Age and sex characteristics are used in both cases to define subgroups, but working with household rather than individual intake data necessitated different specifications of these characteristics. For example, Salathe adjusted for consumption differences by age using ten subgroups for each sex whereas Sexauer's analysis used age of the household head to differentiate those 65 and over from those with a younger household head. A question for future research is how much information might be gained by a more detailed specification of life-cycle stages noted by Sexauer.

Income is used in both studies as a significant variable affecting subgroup means. The effect of household size is also included in each study but in a different manner. Race and

---

R. A. Schrimper is a professor of economics at North Carolina State University.

[1] Sexauer's income effects may be slightly overestimated because they are based on the change in real income before taxes between 1960–61 and 1973–74 rather than the change in real income after taxes. There may be an offsetting effect, however, to the extent that current income involves errors of measurement for permanent income.

region are variables explicitly introduced by Salathe and considered in some preliminary regression analyses by Sexauer. On the other hand, education, employment, and marital status were included by Sexauer but omitted by Salathe in the set of population characteristics selected for evaluating demographic effects on food consumption. If each study had incorporated a more comprehensive list of variables, the estimated aggregate effects of changes in population or demographic characteristics would have been even larger. This observation, however, begs the question of what variables are to be analyzed or considered to represent the effects of changes in demographic or population characteristics. All of us perhaps need to exercise care in using the term demographic effects because it has become increasingly popular in consumption economics and gets used in so many different ways. In view of modern economic analyses of factors influencing household formation, birth, and mortality rates, it may not be totally realistic to even think about differentiating the effects of classic demographic characteristics of age and sex composition of the population from the influence of economic factors on the demand for food.

Much of the interest in this general research area undoubtedly has been generated by the sharp reduction in birth rates during the 1960s and 1970s documented by Salathe. Subsequent changes in age composition of the population may be partly responsible for the slowing of the rate of reduction in the proportion of income allocated to food with higher levels of per capita income that has occurred since the mid-1960s. Salathe's tabulations vividly demonstrate that the largest impact of changes in the age and sex distribution of the population on per capita consumption of individual food commodities between 1950 and 1990 is associated with beverages including milk, coffee, tea, and soft drinks. A large share of these effects certainly results from the change in birthrates affecting the proportion of children who have quite different beverage consumption patterns from the rest of the population in our economy.

In examining the tabulations further, however, I was surprised that the changing age and sex distribution of the population between 1970 and 1990 is projected to affect per capita cheese consumption nearly as much as that of beverage consumption. Since per capita cheese consumption was relatively unaffected by changes in age-sex composition between 1950 and 1970, the effect appears to be operating somewhat differently than that for beverages and suggests the possible influence of a different demographic factor. One hypothesis is that some of the effect may be related to the increasing divergence in male-female mortality rates that is producing an increased ratio of females among the elderly. Unfortunately, Salathe's results do not provide a separate tabulation of the effects of the changing age distribution from the sex composition of the population to readily check this hypothesis. The reason for suspecting that the changing sex composition among the elderly might be a factor influencing future cheese consumption is that cheese is the only food category considered by Salathe for which daily intake for females by each age group over forty is consistently larger than that for males of corresponding ages. Individual age-sex consumption data for poultry also indicate a rather sharp contrast in relative female-to-male rates over age fifty compared to those of earlier ages even though females consistently consumed less than males. This suggests that per capita poultry consumption also may be affected by differential mortality factors for each sex between 1970 and 1990.

It will be interesting to see if the same contrasts in age-sex patterns of food consumption persist when new intake data from the 1977–78 USDA Food Consumption Survey become available. Comparison of the two sets of data to explain differences in particular subgroup averages will be similar to the challenge Sexauer undertook in trying to relate a segment of the 1960–61 and 1973–74 Household Expenditure Data. One issue worth pursuing in comparing the two sets of individual food intake data is determination of how much of the differences associated with age in any given cross-section are the result of economic influences or partly cohort effects as compared to pure age effects. For example, are variations in eating patterns of older people relative to younger segments of the population the result of physiological differences, perceived nutritional requirements, different economic circumstances, or are food habits partly a product of different generations of influences? In other words, is it reasonable to expect all generations to follow the same transformation of eating habits over their life cycle, *ceteris paribus?* If definitive results could lead to a rejection of cohort effects on

food consumption it would strengthen reliability of projections based on gross or net differences among age groups from a given cross-sectional data source. Searching for empirical evidence to address some of these issues seems to be important in continuing to improve our understanding and analyses of demographic effects on food consumption.

Demographic Change and the Demand for Food: Discussion

David W. Price

The papers by Sexauer and Salathe are to be commended for emphasizing the important but frequently overlooked problem of the effects of changing demographic composition of the population. In some instances, these changes have been so slow that they could be overlooked in any time-series analysis, as confirmed by some of Salathe's results. In a study that I did several years ago (Price), it made little difference in a time-series context whether total food expenditures or expenditures for major food groups were placed on a per capita or on a per adult equivalent basis. That is, the age-sex composition of the population did not change fast enough to be an important factor. The results of Sexauer show that for food eaten away from home, demographic changes are important. The question and challenge that Sexauer and Salathe lay down is, for which commodities and for which demographic variables are demographic shifts important? Their results show that the profession cannot continue to assume that demographic changes are slow enough to be assumed away.

The following remarks were induced by Sexauer's paper as Salathe's paper was not received in time for me to make relevant comments. Even though Sexauer's paper appears to be a thorough job, there are questions that remain. From my own perspective, I found the specification of the age and household size effects unsatisfactory. The only two age categories specified are those over 65 and those under 65. The only two household size categories specified were the one-person household and all others. The usual husband-wife, two-person household should be considerably different in many respects from the household with one or more children. The rationale stated, "there was a need to limit the number of classification factors to a reasonable level," does not seem to be an appropriate defense when there are over 10,000 observations. The discussion leaves the reader questioning whether the other types of households were ignored because their proportion in the total sample did not change between sample periods, they were ignored, or their addition made the model too complex. The results cannot tell us what the effect on food expenditures away from home will be if the proportion of children in the population declines. It would be informative to estimate unit equivalent scales for food eaten away from home. The scales would show the amount spent on food away from home by various ages and sexes as a ratio to that spent by the adult male.

Scales are a convenient expression of age-sex differences. They are a vast improvement over a per capita specification which implicitly assumes that food consumption for a child less than six years of age are equal to that of a teenage boy. If we express food expenditure on a household basis as our dependent variable and use the number of persons as an explanatory variable, we are guilty of using the above oversimplifying assumption. The coefficient on the number of persons variable would be larger for the household with teenagers than the household with younger children. Economies-of-size effects will be confounded with age-sex effects.

The unit equivalent scale is not without its difficulties. The basic idea of Sydenstricker and King was to compare food expenditures of households differing in age-sex composition by only one member. For example, the expenditure attributable to a six- to twelve-year-old child is obtained by subtracting the mean expenditure of a household with two adults and one six- to twelve-year-old child from that of a household with only two adults. The two groups of households need to be comparable with respect to income and other relevant characteristics.

Differing income coefficients between households with children and those without lead to instability in the values of the scales. If

David W. Price is a professor of agricultural economics, Washington State University.

the coefficient for households with children is higher than that for households without, the scale values for children will increase as income increases. For prediction purposes, the values of the income coefficients for each type of household are needed along with the scale. Thus, the scale will completely specify age-sex and other effects if coefficients for income and other similar variables are equal for different types of households. If such coefficients are unequal, the scales express only age-sex differences at mean income levels. If income and other coefficient differences are not large, scales may still adequately express age-sex and other effects. If income coefficients differ substantially, scales are only a rough indication of age-sex and other effects. A specification similar to that used by Sexauer might be used along with the scales to specify sociodemographic effects.

In the broader context of methodology, the Sexauer paper makes progress on the basic problems inherent in forecasting. To forecast accurately, one must have stable coefficients. The procedure of disaggregating into groups which hopefully display stable coefficients is an important contribution. Of course, we are not assured that the groups Sexauer has delineated will display stable coefficients over time.

This problem of stable coefficients can be viewed as a problem of scientific laws. The causal law is of the form "all X's have property Y." For example, for a given group of consumers (X's), as income increases by a given percentage, food expenditures increase by a given percentage (property Y). The X's must be defined specifically so that the relationship holds universally. In the example of household behavior, we need to specify for which household, under what conditions there will be a stable relationship between income and expenditures.

Since we cannot state the relationship between income and expenditure with certainty, this type of relationship can be viewed as a statistical law which is of the form "all X's have property Y with probability p." According to Hemple, little modification is needed in the basic framework of explanation and prediction when statistical laws are used instead of causal ones. Thus, the same problems of the adequacy of the basic laws exist whether statistical or causal.

Viewing the specific relationship between income and expenditure as a scientific law, we must specify the "boundary" conditions under which this law will hold. I am not referring here to the more general form of Engel's law between income and food expenditure, but a specific statement as to the size of the income coefficient or elasticity. For forecasting, we need to specify the boundary conditions for the specific coefficient to be stable. For example, the conditions may consist of the following: a one-person household with the person being employed, with a college education, belonging to social class y, having a psychological need for food of level z.

The above is, of course, little more than a guess as to what the boundary conditions may look like. Our lack of knowledge of boundary conditions demonstrates a major weakness in the profession of agricultural economists (Kelso). We cannot successfully predict or explain adequately economic phenomena without them. Boundary conditions can be specified with the use of theory and empirical experiment. Sexauer's work is a start. To fill in the missing pieces, we need to analyze different data sets which let us look at households under different situations. The theory which suggests what variables affect the income-food expenditure relationship needs considerable improvement. We have little idea if and what any sociological or psychological variables may affect this relationship.

References

Hemple, Carl G. "Probabilistic Explanation." *Readings in the Philosophy of Science*, ed. Baruch H. Brody, pp. 22–38. Englewood Cliffs, N.J.: Prentice-Hall, 1970.

Kelso, M. M. "A Critical Appraisal of Agricultural Economics in the Mid-Sixties." *J. Farm Econ.* 47(1965): 1–18.

Price, David W. "Unit Equivalent Scales for Specific Food Commodities." *Amer. J. Agr. Econ.* 52 (1970):224–33.

Risk Preferences of Agricultural Producers: Their Use in Extension and Research

Douglas L. Young

Most models of decision making under risk require knowledge of decision makers' willingness to bear risk, or equivalently, knowledge of their risk preferences. This is true both for positive applications of risk theory that explain or predict behavior under uncertainty for purposes of policy evaluation and for normative applications which advise decision makers which decisions they should make given their feelings toward risk.

The specific objectives of this paper are: (*a*) to review and evaluate critically the current state of knowledge on risk preference measurement methods and empirical results for individual agricultural producers, and (*b*) to suggest directions for future research and extension applications requiring information on risk preferences of individual producers. The implications of aggregate (industry) risk preferences as in risk supply response studies will not be included in this review.

Concepts of Risk and Risk Preferences

The behavorial decision model employed determines the appropriate concept of risk in a particular application. The popular Bernoullian expected utility decision criterion utilizes an objective function that is a function of (potentially) all the statistical moments of the (usually profit) outcome of the risky actions, a_i, $i = 1, \ldots, n$, available to the decision maker. In practice, it has been popular among empiricists to assume that the underlying utility function was quadratic or that profits were normally distributed yielding the simpler function of mean and variance only

$$(1) \qquad \max_i \; (EU)_{a_i} = f(\mu_{a_i}, \sigma_{a_i}^2).$$

Accepting (1), variance (or a related measure of dispersion such as standard deviation or coefficient of variation) is clearly the appropriate "measure of risk." Aside from the plethora of conceptual and methodological issues concerning whether the variance should be subjective or objective and how it should be elicited or measured (see Anderson, Dillon, Hardaker), two fundamental potential limitations characterize the "variance as risk" concept embedded in (1). First, if the decision maker is concerned about higher moments of the action-outcome probability distributions, "risk" should be represented by a vector containing variance of profit, skewness of profit, kurtosis of profit, and so on. Secondly, the convenient scalar measure of risk is based on a utility function considering only the single-attribute of profit. Agricultural producers may, in fact, base their decisions upon such multiple objectives as profits, leisure-work consequences, and personal "aesthetic" considerations.

A distinctly different set of risk concepts are implied by the various non-Bernoullian decision models. For example, the "minimax" model would identify the maximum loss of an action, regardless of how remote the probability of its occurrence, as a measure of the riskiness of the action. The lexicographic "safety first" model identifies the probability (α) that random profit (Π) will fall below some critical or "disaster" level (d) as risk, formally

$$(2) \qquad Pr\,(\Pi \leq d) = \alpha.$$

Most formal definitions of risk aversion rely on the Bernoullian conclusion that risk preferences can be encoded in a utility function for money (income or wealth) and the associated expected utility function as in (1). Positive marginal utility of income (i.e., $U'(M) > 0$) is commonly assumed for the utility function. Within the framework of Bernoullian decision

---

Douglas Young is an assistant professor and assistant agricultural economist at the Department of Agricultural Economics, Washington State University.

This is Washington College of Agriculture Research Center Scientific Paper No. 5395.

This paper draws on two more detailed papers on this topic (Young and Findeis; Young et al. 1979) stemming from the author's involvement on Western Regional Research Project, W-149. Helpful suggestions from several fellow W-149 project participants on earlier versions of this paper are gratefully acknowledged.

theory, the following measures yield equivalent risk preference classifications: (*i*) $U''(M)$, (*ii*) $-U''(M)/U'(M)$, (*iii*) $\partial EU/\partial\sigma^2$, (*iv*) $(d\mu/d\sigma^2)_{EU=\text{constant}}$, and (*v*) the risk premium. A decision maker is classified as risk averse, risk neutral, or risk preferring, respectively, as measures (*i*) or (*iii*) are less than, equal to, or greater than zero. For measures (*ii*), (*iv*), and (*v*), the inequalities are reversed to indicate the respective classifications. A Bernoullian utility function is unique only up to a positive linear transformation; the same action will maximize expected utility for $Z = a + bU$, $b > 0$, as for U. In recognition of this property, Pratt developed $-[U''(M)/U'(M)]$ as a unique measure of absolute risk aversion which yields the same value for both Z and U. Pratt also defined $-[U''(M)/U'(M)]M$ as a measure of relative risk aversion. Definition (*iii*) directly measures the impact of a change in risk (σ^2) on expected utility. Definition (*iv*), attributable to Magnusson, represents the marginal rate of substitution between risk and expected income.

An intuitively attractive measure of the degree of risk aversion is the amount an individual will willingly pay to avoid participation in a fair bet, or the risk premium. More generally, the risk premium for a risky action is the difference between its expected monetary value and its certainty equivalent. The certainty

tween certain outcomes and risky options involving hypothetical gains and losses. After a series of points in U-M space have been identified in the interview, an explicit utility curve can be fitted to the points by regression analysis.

The DEU technique has been criticized as subject to bias arising from different interviewers, preferences for specific probabilities (for example, a 50:50 bet), confounding from extraneous variables, and negative preferences toward gambling (Roumasset, Binswanger 1978b). Choice of an inappropriate functional form for the utility function can lead to undesirable implications (Lin and Chang). Also, utility associated with the outcome of a particular risky action is probably dependent upon more variables than monetary gains and losses alone. Inability to hold these other variables constant while eliciting single attribute utility functions is likely to lead to substantial imprecision.

In my view, even if the above "technical" sources of bias could be removed by refined interviewing and econometric techniques, the representativeness of choices involving hypothetical gains and losses in a parlor game setting could be questioned. Does a utility function elicited in a short interview around a farmer's living room coffee table reflect his attitudes toward risk in real world decisions?

Table 1. Empirical Studies of Risk Preferences of Individual Farmers: A Summary

Source	Description of Sample	Method[a]	Sample Size	Percent Distribution of Sample by Risk Classification: Averse	Neutral	Preferring	Mixed[b]
Binswanger	Indian farmers and landless laborers	EM					
		0.50 real[c]	119	71	0	19[d]	—[e]
		5.00 real[c]	117	84	0	9[d]	—[e]
		50.00 real[c]	118	89	0	2[d]	—[e]
		500.00 hyp.[c]	118	97	0	1[d]	—[e]
Conklin, Baquet, and Halter	Oregon orchardists	*DEU*	8	37	0	13	50
Dillon and Scandizzo	Brazilian small farmers and sharecroppers	*DEU*[f]					
		Owners, *SA*[g]	56	70	9	21	—[e]
		Sharecroppers, *SA*[g]	47	58	8	34	—[e]
		Owners, *SR*[g]	56	87	0	13	—[e]
		Sharecroppers, *SR*[g]	47	79	0	21	—[e]
Francisco and Anderson	Australian pastoralists	*DEU*	21	0	0	5	95
Halter and Mason	Oregon grass seed growers	*DEU*	44	33[h]	33[h]	33[h]	—[e]
Lin, Dean, and Moore	Large scale California farmers	*DEU*	6	50	33	0	17
McCarthy and Anderson	Australian beef ranchers	*DEU*	17	48	29	23	0
Officer and Halter	Australian wool producers	*DEU*					
		I, *MVM*[i]	5	60	20	20	0
		II, *MVM*[i]	5	40	40	0	20
		I, *RAM*[i]	5	20	0	60	20
		II, *RAM*[i]	5	80	0	20	0
Webster and Kennedy	Australian sheep and grain farmers	*DEU*					
		EF[j]	5	80	0	0	20
		MVM	5	100	0	0	0
Brink and McCarl	Corn Belt farmers (U.S.A.)	*OEB*	38	66	34	0	—[e]
Moscardi and de Janvry	Mexican peasant farmers	*OEB*	45	100	0	0	—[e]

[a] *EM* is experimental method; *DEU*, directly elicited utility; *OEB*, observed economic behavior.
[b] "Mixed" indicates presence of both risk-averse and risk-preferring ranges.
[c] Real payoff levels of 0.5, 5, and 50 rupees and hypothetical payoff of 500 rupees.
[d] Percentages do not sum to 100 due to "inefficient" respondents.
[e] Methodology precluded "mixed" classifications.
[f] *DEU* approach used but no explicit utility functions estimated.
[g] *SA* is subsistence assured; *SR* is subsistence at risk.
[h] Halter and Mason only reported "that the number (of classifications) falling into each category was about equal" (p. 105).
[i] I is year, II is year 2; *MVM*, modified von Neumann-Morgenstern method; *RAM*, Ramsey method.
[j] *EF* is expected income versus focus-loss income tradeoff approach; *MVM*, modified von Neumann-Morgenstern method.

chological research, for measuring risk preferences of more than 350 peasants in rural India. This approach involved use of actual financial compensation at significant levels, was conducted in a series of several visits over five or more weeks which permitted the respondent ample time to reflect on each decision and discuss it with others if desired, and required only a simple choice among eight gambles, which outcomes were determined by a flip of a coin. Impressive efforts were made to teach respondents the nature of the game, to elicit responses reflecting true feelings, to avoid interview bias, and to eliminate other sources of error. Binswanger developed the experimental approach after rejecting the DEU interview method. His field checks on the interview method led him to conclude " . . .

that evidence on risk aversion from pure interviews is unreliable, nonreplicable and misleading, even if one is interested only in a distribution of risk aversion rather than reliable individual measurement" (1978a, p. 45).

The realistic experimental approach utilized by Binswanger goes far in remedying some of the more serious measurement flaws of the DEU method. It is less obvious that such games could be funded for realistic levels of gains associated with major farm decisions in the United States. Binswanger spent approximately $2,500 for prize money in his Indian experiment. He estimated a comparable experiment in the United States would require $150,000 for prizes alone—an amount he implies is not unreasonable given the cost of many modern research projects (1978b, p. 54).

Observed Input Demand and Output Supply Behavior

The doubts surrounding the validity of directly elicited utility functions have encouraged researchers to seek indirect measures of risk preferences. This approach compares observed economic behavior with respect to factor demand and output supply to behavior predicted by theoretical models incorporating risk and risk preferences. For example, expected utility maximization under risk leads to first order conditions of the form (Magnusson, p. 65; Anderson, Dillon, Hardaker, p. 163).

$$(3)\quad E(MVP_i) = MFC_i + R_a I_r, \quad i = 1, \ldots, n$$

where $E(MVP_i)$ is expected marginal value product of input i, MFC_i is nonstochastic marginal factor cost of input i, and $R_a I_r$ is a "risk adjustment." R_a is the entrepreneur's local risk aversion coefficient as described by definition (*iv*) above and I_r is the marginal contribution to risk of additional input use. Assuming I_r is positive, risk aversion ($R_a > 0$) implies a positive "risk adjustment"; i.e., a risk-averse, expected utility-maximizing entrepreneur will "stop short" of equating $E(MVP)$ to MFC. (See Wolgin, and Young 1979, for an extension of this approach to the multiple-product firm case.)

Equation (3) indicates a theoretical approach for solving for R_a in terms of empirically observable magnitudes,

$$(4)\qquad R_a = [E(MVP_i) - MFC_i]/I_r.$$

In practice, however, obtaining appropriate estimates of I_r can be difficult without invoking excessively restrictive assumptions on the sources and functional specification of stochastic influences. Pope has proposed an econometric approach, based on the OEB concept, that provides estimates of an assumed constant risk aversion coefficient under certain assumptions. Moscardi and de Janvry have utilized this OEB approach within a safety first framework.

On the supply side, Brink and McCarl derived indirect estimates of risk aversion coefficients of thirty-eight large Corn Belt farmers by comparing their elicited cropping plans to those predicted by a variant of Hazell's MOTAD linear programming model. The value of the parametrically varied risk aversion coefficient that minimized the difference between the model's predicted plan and the farmer's actual plan was selected to represent the farmer's risk preferences.

The OEB approach shares with the DEU method the advantage of furnishing measures of risk aversion that can be incorporated directly into models of economic decision making under risk. In addition, however, the OEB approach escapes the compelling criticism that the revealed risk preferences may not be germane to real world decisions. Unfortunately, the OEB method is vulnerable to serious errors of inference. Because it measures risk preferences on the basis of the difference between actual factor use or output supply levels and the levels associated with the (risk-neutral) expected profit-maximizing solution, it attributes the entire difference to risk aversion. In actual fact, many other explanations such as inaccurate or incomplete technical and market information, different resource endowments, capital constraints, different objective functions, and different subjective probability assessments could underlie some or all of the residual attributed to risk aversion.

Empirical Findings on Individual Producer Risk Preferences

In assessing the empirical evidence in table 1 it is important to consider the quality of the samples represented. Overall, risk preferences have been elicited for a very small number of agricultural producers. Furthermore, there was no attempt in most studies to achieve industry representativeness in sample selection. These sample limitations, combined with previously cited measurement problems,

make generalizations from the evidence in table 1 to the general populations extremely tenuous.

One tentative conclusion is that farmers in less developed countries appear to be more uniformly risk averse than their wealthier counterparts in developed countries. Among the studies of Australian and American farmers, approximately 50% of the sampled individuals manifested risk-preferring attitudes over at least some ranges when the measurement technique did not preclude this possibility. Risk-neutral or risk-preferring attitudes over some ranges among a significant fraction of agricultural producers in developed countries cannot be excluded on the basis of the available evidence. The greater incidence of risk aversion in developing countries is consistent with the widely accepted hypothesis of decreasing absolute risk aversion with respect to wealth.

Only the studies by Moscardi and de Janvry, Dillon and Scandizzo, Binswanger, and Halter and Mason, among those reviewed, focused explicitly on the relationship between producer attributes and risk preferences. Overall, few consistent relationships emerged over all four studies. The one exception was a positive correlation between education and the willingness to bear risk.

Potential Uses of Producer Risk Preferences: Review and Research Recommendations

To recommend directions for future research on risk preferences, it is necessary to ask why it is important to know producer risk preferences in the first place? Recognizing the added cost of measuring risk preferences and the unproven reliability of the measures, it is necessary to evaluate within the context of the specific problem whether attempted measurement is worthwhile. For many problems, some alternative approach may be more appropriate. Implications for future research are discussed below under three important areas of potential application.

Farm Management Extension Applications

The desire to tailor extension farm management recommendations to the current risk preferences of particular farmers provides one potential justification for measuring individual risk preferences. Although this application is recommended by some advocates (Makeham, Halter, Dillon), time, cost, and practical problems associated with direct elicitation of utility functions are likely to limit their use in extension programs. Even if researchers were to hand an extension worker an elaborate set of equations relating risk aversion at all relevant loss and gain levels to personal and business attributes for farmers in his district, the personal and evolutionary nature of attitudes toward risk would probably prevent their confident application to specific individuals. There likely exists considerable heterogeneity in risk preference among individuals with superficially common business and personal characteristics (recall evidence in table 1). Furthermore, evidence from psychological studies suggests that the behavioral predictive power of an individual's willingness to bear monetary risk is likely to change from situation to situation given the multiobjective nature of most decisions (Schneider, pp. 390–96). Changing objectives, information, and attitudes could make an individual's risk aversion coefficient an elusive moving target.[1] Neither farmers nor field extension personnel are likely to consent to obtaining personal updatings of utility functions or safety first margins every time a new recommendation is given.

In light of the above discussion, what should extension specialists and researchers interested in developing materials and models with extension applications do to incorporate risk considerations? Some specific recommendations which do not require elicitation of individual risk preferences are:

(*a*) Extension specialists should provide more and better information on alternative decision options and their objective outcome probabilities. They also should devote more effort to teaching principles of decision making and information utilization as exemplified by the excellent recent national SEA-Extension project, "Dealing With Risk In Farm Decision Making."

(*b*) Researchers constructing normative decision models for use by farmers should use risk aversion indices that are sufficiently simple and intuitive that they can be supplied by the farmer himself. Alternatively, these mod-

[1] An alternative hypothesis is that risk preferences are relatively stable over time, but that changing behavior under risk is due to varying constraints and changing subjective assessments of expected values and variances. The area of expectation formation processes requires more research to resolve satisfactorily this question.

els might incorporate decision rules that depend upon objectively measurable financial ability to bear risk. Hardin and Walker, for example, required that a farmer exceed a minimum equity ratio in order to assume the risk of borrowing in a land investment analysis.

(*c*) Researchers can rank decision options on the basis of rules of stochastic dominance. Meyer's criterion for identifying risk efficient decisions for decision makers whose risk aversion functions fall between certain bounds is a promising method for certain prescriptive models (Robison and King).

Technology Transfer and Rural Development Applications

Estimating single-attribute risk aversion coefficients of peasant farmers and relating them to socioeconomic variables as in Moscardi and de Janvry is probably not the most efficient method of predicting their willingness to adopt new technology or participate in rural development programs. If technology adoption or development program participation is of primary concern, it seems appropriate to use these phenomena as dependent variables directly, and to include all relevant factors as independent variables. A review by Havens of variables commonly used in technology adoption studies listed: (*a*) size of operation, (*b*) education, (*c*) social status, (*d*) contact with information, and (*e*) social participation. Other variables such as age, local group identification, opinion leadership, management practices, and attitude toward credit have also been used but less frequently.

Microeconomic Policy and Predictive Applications

It has been argued that farm management extension and development program planning applications generally do not justify measurement of individual risk preferences, or at least not formal measures based on directly elicited utility functions. In the area of microeconomic policy and predictive applications, however, such measures sometimes are justified. The studies by Baquet, Halter, Conklin; Harris and Nehring; and Lin, Carman, Moore, Dean provide examples of such applications.

A danger in such application is that the difficulty or cost of eliciting utility functions for more than a small, possibly unrepresentative, sample of farmers will reduce the studies to methodological excursions rather than practical policy evaluation tools. This danger seems to have been realized, at least in part, in both the Baquet, Halter, and Conklin and Harris and Nehring studies as reflected in extensive qualifications of their results (see Baquet, Halter, Conklin, p. 519, and Harris and Nehring, p. 166). Researchers must seriously ask themselves, especially for applications where results are not highly sensitive to risk preferences, whether ignoring risk preferences will increase their chances of developing quantitative results for a larger and more representative sample of the population so that their conclusions will be of practical value to policy makers.

A policy area of particular importance at the current time justifying incorporation of risk considerations is the dynamic structural and distributive implications of income instability in agriculture and of public policies to mitigate such instability. What are the relationships between risk preferences and structural features, especially farm size and legal form of ownership? For example, are larger or corporate farmers generally less risk averse than small or family farmers who are sole proprietors? A second, not unrelated, group of hypotheses involves examining the frequently assumed positive relationship between accounting measures of financial ability to bear risk and willingness to bear risk. A related research priority is the need to examine the differential historical capacity of farms of different sizes and types to survive and to maintain profitability under price and yield instability. Studies by Lin and Ingerson, Anderson, and Moore provide tentative evidence that small farms may benefit relatively from increased income stability, but much more empirical work is needed in this area.

Which methodologies appear most fruitful for measuring risk preferences for use in microeconomic policy and predictive applications? If the problem strictly requires risk preferences of individual producers rather than "typical" preferences of designated classes of producers, the experimental method as utilized by Binswanger seems most likely to provide reliable replicable measures of risk aversion, assuming the method is adequately funded and conscientiously executed.

In applications where objectives other than profit alone are likely to be important, serious consideration should be given to utilizing a multiobjective decision model (Keeney and

Raiffa). In certain cases, a certainty multi-objective approach may be preferable to a single-attribute risk model.

If "typical" or average risk preferences of designated classes of farmers are required, two methodological options are available. The first approach is typically carried out in two stages: (*a*) estimate risk aversion coefficients for a large sample of individuals whose members vary according to the class attributes of interest, and (*b*) describe the relationship between risk aversion level and personal or business attributes. Regression analysis and multivariate statistical techniques are statistical tools which can be used to describe these relationships (Binswanger 1978a, Dillon and Scandizzo, Moscardi and de Janvry, and Halter and Mason).

The second (OEB) approach would be to estimate aggregate risk aversion coefficients or risk responses of designated classes of farmers directly with econometric or risk-programming models. Risk response models which bypass the direct estimation of formal risk aversion coefficients to focus directly on the measured impact of risk on the variable of interest should be seriously considered whenever their estimation is feasible. Data availability is likely to pose the greatest constraint to the use of this method. Aggregate time series data are unlikely to be available, for example, to estimate separate risk-response acreage supply functions for small and large farmers.

References

Anderson, J. "Risk and Farm Size in the Pastoral Zone." *Aust. J. Agr. Econ.* 16(1972):1–9.

Anderson, J., J. Dillon, and J. Hardaker. *Agricultural Decision Analysis.* Ames: Iowa State University Press, 1977.

Baquet, A., A. Halter, and F. Conklin. "The Value of Frost Forecasting: A Bayesian Appraisal." *Amer. J. Agr. Econ.* 58(1976):511–20.

Binswanger, H. *Attitudes Towards Risk: Experimental Measurements in Rural India.* Economic Growth Center Disc. Pap. No. 285, Yale University, 1978a.

———. *Attitudes Towards Risk: Implications for Economic and Psychological Theories of an Experiment in Rural India.* Economic Growth Center Disc. Pap. No. 286, Yale University, 1978b.

Brink, L., and B. McCarl. "The Tradeoff between Expected Return and Risk among Corn Belt Farmers." *Amer. J. Agr. Econ.* 60(1978):259–63.

Conklin, F., A. Baquet, and A. Halter. *A Bayesian Simulation Approach for Estimating Value of Information: An Application to Frost Forecasting.* Oregon State Univ. Agr. Exp. Sta. Tech. Bull. No. 136, May 1977.

Dillon, J., and P. Scandizzo. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach." *Amer. J. Agr. Econ.* 60(1978):425–35.

Francisco, E. and J. Anderson. "Chance and Choice West of the Darling." *Aust. J. Agr. Econ.* 16(1972):82–93.

Halter, A. N., and Robert Mason. "Utility Measurement for Those Who Need to Know." *West J. Agr. Econ.* 3(1978):99–109.

Hardin, Mike, and Odell Walker. "A Simulation Analysis of Land Investment in North Central Oklahoma under Alternative Futures for Agriculture." Paper presented at WAEA Meetings, Bozeman, Mont., 23–25 July 1978.

Harris, D., and R. Nehring. "Impact of Farm Size on the Bidding Potential for Agricultural Land." *Amer. J. Agr. Econ.* 58(1976):161–69.

Havens, A. *A Review of Factors Related to Innovativeness.* Mimeographed. Ohio State Univ. Agr. Exp. Sta. Bull. A. E. 329, 1962.

Hazell, P. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1971):53–62.

Keeney, R. L., and H. Raiffa. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs.* New York: John Wiley & Sons, 1976.

Lin, W., and H. Chang. "Specification of Bernoullian Utility Functions in Decision Analysis." *Agr. Econ. Res.* 30(1978):30–36.

Lin, W., and Ann Ingerson. "Impacts of Price Stabilization Policy on Farm Structure." Paper presented at the AAEA–CAES annual meetings, Blacksburg, Virginia, 6–9 Aug. 1978.

Lin, W., G. Dean, and C. Moore. "An Empirical Test of Utility vs. Profit Maximization in Agricultural Production." *Amer. J. Agr. Econ.* 56(1974):497–508.

Lin, W., H. Carman, C. Moore, and G. Dean. "Producer Response to Income Taxes: An Empirical Test within a Risk Framework." *National Tax J.* 27(1974):183–96.

Magnusson, G. *Production Under Risk: A Theoretical Study.* Uppsala, Sweden: Almqvist and Wiksells, 1969.

Makeham, J., A. Halter, and J. Dillon. *Best-Bet Farm Decisions.* Sydney, Australia: Southwest Press Pty Ltd., Professional Farm Management Guidebook No. 6, 1968.

McCarthy, W., and J. Anderson. "Applied Aspects of Farmer Decision Making." *Conference Proceedings of the Committee on Economics of Range Use and Development,* pp. 141–59. Western Agricultural Economics Research Council Rep. No. 8, 1966.

Meyer, Jack. "Choice among Distributions." *J. Econ. Theory* 14(1977):326–36.

Moore, C. "Income Variability and Farm Size." *Agr. Econ. Res.* 17(1965):108–15.

Moscardi, E., and A. de Janvry. "Attitudes toward Risk among Peasants: An Econometric Approach." *Amer. J. Agr. Econ.* 59(1977):710–16.

Officer, R., and A. Halter. "Utility Analysis in a Practical Setting." *Amer. J. Agr. Econ.* 50(1968):257–77.

Pope, Rulon. "Econometric Analysis of Risk Models—Some Explorations and Problems." Paper presented at WAEA Meetings, Bozeman, Montana, 23–25 July 1978.

Pratt, J. "Risk Aversion in the Small and in the Large." *Econometrica* 32(1964):122–36.

Robison, Lindon, and Robert King. "Specification of Micro Risk Models for Farm Management and Policy Research." Paper presented at WAEA Meetings, Bozeman, Montana, 23–25 July 1978.

Roumasset, James A. *Rice and Risk: Decision Making among Low Income Farmers*. Amsterdam: North-Holland Publishing Co., 1976.

Schneider, David J. *Social Psychology*. Reading, Mass. Addison-Wesley, 1976.

Webster, J., and J. Kennedy. "Measuring Farmers' Tradeoffs between Expected Income and Focus Loss Income." *Amer. J. Agr. Econ.* 57(1975):97–105.

Wolgin, J. M. "Resource Allocation and Risk: A Case Study of Smallholder Agriculture in Kenya." *Amer. J. Agr. Econ.* 57(1975):622–30.

Young, Douglas. "Resource Allocation and Risk: A Case Study of Smallholder Agriculture in Kenya: Comment." *Amer. J. Agr. Econ.* 61(1979):111–13.

Young, Douglas, and Jill Findeis. "Characteristics of Producers: Their Willingness and Ability to Bear Risk." Paper presented at WAEA Meetings, Bozeman, Mont. 23–25 July 1978.

Young, Douglas, William Lin, Rulon Pope, Lindon Robison, and Roger Selley. "Risk Preferences of Agricultural Producers: Their Measurement and Use." *Proceedings of 1979 Annual Meeting of Western Regional Research Project W-149*, pp. 1–28. Dep. Agr. Econ. AE-4478, University of Illinois, Jul. 1979.

Analysis of Risk Management Strategies for Agricultural Producers

Harry P. Mapp, Jr., Michael L. Hardin, Odell L. Walker, and Tillak Persaud

Uncertainty is a pervasive phenomenon in production agriculture. Many factors, including weather events, diseases, insect infestations, general economic conditions, the development and adoption of technological innovations, and public and private institutional policies, interact to create a unique decision making environment for the agricultural producer. Institutions and the uncertainty surrounding the development and implementation of their policies have become increasingly important to farm operators. Today, perhaps to a greater extent than they would like, producers must respond to energy policy which affects the availability and cost of fuels, and trade policy which influences exports and imports of agricultural supplies and products. Farmers' decisions are influenced by environmental policy which specifies the types and quantities of pesticides and herbicides available and legislates safe levels of usage. Financial institutions have increased farm borrowers' risk of interest rate increases by adopting floating and variable interest rates.

Each of these factors along with vagaries of nature and markets contributes to the price, yield, or net return variability of agricultural producers. Institutional innovations, such as disaster payments, emergency loans, and federal crop insurance, are designed to shift a portion of the adverse effects of price and yield variability from the private to the public sector. The proposed Farm Production Protection Act of 1979 would provide varying amounts of protection and guarantee compensation for crop losses due to crop failure or natural disasters through an insurance program with the producer's premium subsidized by the government (Miller and Trock). Participation in these programs depends upon the decision maker's perceptions of the potential benefits and costs, and his attitude toward risk.

The specific purposes of this paper are (*a*) to review research both recently completed and currently in progress on approaches being used to assess and respond to production, market, and financial risks in agriculture; and (*b*) to present an evaluation of production and marketing strategies designed to minimize variability of net farm income subject to receiving a specified level of income for a southwestern Oklahoma farm operation; and (*c*) to relate the effects of alternative assumptions regarding beginning equity level, rate of increase in land value, and rate of increase in the cost of agricultural inputs to the probability of "success" of risk efficient farm plans for the southwestern Oklahoma operation.

Review of Recent Research Approaches

A number of firm-level studies have focused on whole farm planning under conditions of risk and uncertainty. An approach frequently used is quadratic risk programming (Fruend; Kliebenstein and Scott). Researchers using this approach usually assume that the decision maker maximizes expected utility and either the utility function is quadratic with respect to expected income and variance of income or net returns of the production activities follow a multivariate normal distribution. Historical price, yield, and cost data provide the basis for

Harry P. Mapp, Jr. is a professor, Michael L. Hardin is an assistant professor and extension economist, Odell L. Walker is a professor, and Tillak Persaud is a graduate research assistant in the Department of Agricultural Economics at Oklahoma State University.

Journal Article No. J-3676 of the Oklahoma Agricultural Experiment Station.

calculating net returns associated with each production activity. The model is solved to determine the set of production activities that minimizes variance of net returns subject to receiving a specified level of income or to develop the efficiency frontier showing tradeoffs between expected income and variance of income.

Hazell developed an approach which minimizes total absolute deviation rather than variance, which may be solved using a linear programming algorithm, and which gives results remarkably similar to those of quadratic programming. This approach, referred to as MOTAD, had been applied successfully to several different types of problems (Brink and McCarl; Nieuwoudt, Bullock, Mathia; Simmons and Pomareda; Schurle and Erven).

An alternative approach to studying the effects of risk and uncertainty at the firm level has involved development of firm level simulation models. Patrick studied the effects of debt levels and loan arrangements on a farm firm survival and growth. Held and Helmers developed a financial simulation model to investigate firm growth, income, and survivorship relationships in wheat farming. Hardin also developed a simulation model to evaluate risk and financial management implications of major capital investments in an uncertain environment.

This analysis uses both MOTAD and simulation models to evaluate risk efficient farm plans under alternative economic futures. The analysis simulates the potential effects of reduced rates of increase in land value, increased costs of production, and alternative beginning equity levels on the viability of risk efficient farm plans developed on the basis of historical data in a MOTAD framework.

Farm Situation and Data Requirements

A typical farm situation for southwestern Oklahoma was defined for the MOTAD-simulation analysis. The farm contains 1,200 acres of cropland and 300 acres of native pasture. Crop activities in the model include alfalfa, cotton, grain sorghum, wheat, barley, and oats. Both models require data on variability for each activity. Experimental plot data from field stations in southwestern Oklahoma were analyzed and a series of trend-adjusted annual yields for each activity was estimated for the period 1965–77.

Activities for steers and heifers on wheat pasture and summer stockers were included in the model. Experimental data did not exist to establish yield variability for the livestock activities. Oklahoma crop and livestock price series for 1965–77 were obtained for each activity in the model. Product prices were adjusted for trend where appropriate and expressed in constant (1977) dollars. Oklahoma crop and livestock budgets were used to establish the 1977 cost of production for each activity. The Index of Prices Paid by Farmers was used to generate the cost of production series from 1977 back to 1965 for each activity. The result was then expressed in 1977 dollars.

Gross margins for each activity were calculated by subtracting the variable cost of production during each year from the appropriate gross revenue in that year. Estimated gross margins for selected crop and livestock activities used in the MOTAD analysis are presented in table 1. Triangular distributions reflecting these relationships along with correlations among activity yields and prices were used in the simulation analysis. The triangular distributions were defined by specifying the maximum, minimum, and modal values for each activity.

Production assets for the hypothetical 1,500 acre dryland farm include land and buildings valued at $855,000 and machinery valued at $70,000. Production liabilities were confined to real estate debt of $270,628. Beginning equity is $654,372 (70%). In part of the study described later, real estate and machinery debt are increased to create a beginning equity of 45%.

Development of MOTAD and Simulation Models

The MOTAD model used to develop risk efficient farm plans is a variation of linear programming. The MOTAD model formulation used in this study was

$$\text{(1)} \quad \text{Minimize } Ld^{-}$$
$$\text{subject to:}$$
$$\text{(2)} \quad A\,X \leq B,$$
$$\text{(3)} \quad DX + Id^{-} \geq 0,$$
$$\text{(4)} \quad C'X = \lambda, \text{ and}$$
$$\text{(5)} \quad X,\, d^{-},\, \lambda \geq 0,$$

where X, A, B, and C represent activity levels, resource requirements, resource availabilities, and gross margin expectations, respectively.

Table 1. Estimated Gross Margins in Constant (1977) Dollars for Selected Crops, Southwestern Oklahoma

Year	Wheat Sale at Harvest	Cotton	Grain Sorghum	Winter Steers	Summer Steers
	($/AC)			($HD)	
1965	23.03	64.51	36.21	31.50	53.77
1966	76.62	−55.84	17.74	69.28	8.08
1967	35.55	72.55	38.03	20.14	27.03
1968	−29.57	−6.35	38.71	35.25	24.14
1969	43.95	87.56	43.04	56.86	11.61
1970	17.10	39.86	34.21	73.06	26.30
1971	−29.89	85.54	19.65	34.95	60.49
1972	−32.30	−16.66	38.41	64.66	90.63
1973	35.86	−61.90	130.91	134.35	35.20
1974	135.24	22.53	106.71	−21.14	−45.85
1975	57.77	24.77	98.72	6.86	69.52
1976	86.37	89.12	35.70	61.75	−22.38
1977	48.56	113.37	29.08	44.38	15.96
Mean	36.02	35.31	52.86	47.07	27.27
Standard deviation	48.79	56.99	34.92	37.57	36.78
Coefficient of variation	135.44	161.38	66.05	79.82	134.87

Gross margin is defined as gross return minus total variable cost. The gross margin expectation is the mean of the series. The difference between the observed gross margin and the gross margin expectation in a given year is an element of D, the matrix of deviations. The vector $\mathbf{d}^-$ represents yearly total negative deviations summed over all risky activities. $\mathbf{Ld}^-$ represents the summed total negative deviations over all years. λ is a scalar used to represent the income constraint. The efficiency frontier may be traced out by parameterizing λ from zero to its maximum value.

The simulation model, described in detail by Hardin, traces the operation of the firm thru a specified planning horizon under stochastic prices and yields. The simulation model generates cash flow data used in present value and feasibility analysis for the farm and balance sheet information needed to determine if equity is sufficient to maintain the financial viability of the farm thru the planning horizon. For the alternative plans developed by MOTAD, the simulation model can answer questions such as "Is the plan financially feasible given the farmer's consumption needs, initial financial position, and potential income distribution over the planning horizon?" The simulation model evaluates the effects of interactions between years which is not possible with the MOTAD model. The risk management strategy to be simulated is specified as input data for the model. Alternative assumptions regarding the future economic trends are specified. In this analysis, changes in the rate of increase in land values and input prices were evaluated for alternative beginning equity levels.

Analysis and Results

The MOTAD model was used to analyze a base plan and two risk management scenarios. The base plan (the linear programming solution) assumes the farm operator chooses from a set of production activities which involve sale of the product at harvest and that his objective is to maximize gross margins. In the first risk management scenario, the producer is assumed to minimize total negative deviations from the gross margin expectations, subject to receiving a specified level of income. The second risk management scenario assumes that storable commodities, such as wheat, may be marketed at harvest or sequentially during the crop year. Storage costs are accounted for and the producer may sell any portion of the stored wheat during any month of the crop year. In addition, this scenario permits consideration of forward contracting for a portion of the wheat crop. The forward contracting activity assumes the producer contracts in March for June delivery.

The solutions determined under the base plan and the two risk scenarios are presented

Table 2. Programming Solutions under Three Production and Marketing Scenarios

Activities in the Optimum Solution	Units	Profit-Maximizing Solution—Sale at Harvest	MOTAD Solution—Sale at Harvest	MOTAD Solution—Sequential Marketing and Forward Contracting
Steers	Head	171	233	222
Grain sorghum	Acres	1172	918	866
Alfalfa	Acres	28	28	28
Cotton	Acres		65	150
Wheat—sell in June	Acres		189	
Wheat—sell in December	Acres			60
Wheat—forward contract in March for June sale	Acres			96
Gross margins	Dollars	66,340	65,000	65,000
Standard deviation[a]	Dollars	41,360	36,100	33,605

[a]Standard deviation is estimated by multiplying the objective function value from MOTAD (Ld^-) by a constant K. K is calculated as $K = 2/t\sqrt{\frac{t \cdot \pi}{2(t-1)}}$, where $t = 13$, the number of years in the series, and $\pi = 3.14286$ (Hazell).

in table 2. When production and sale at harvest are the only alternatives, the profit maximizing organization of production is very specialized. Only two crop activities enter the solution—1,172 acres of grain sorghum and 28 acres of alfalfa. In addition, 171 steers are included in the solution. Gross margins total $66,340 and standard deviation is $41,360. Risk is assumed to be of no importance to the producer in the base plan. This solution represents the maximum profit point on the efficiency frontier.

The first risk management scenario assumes the producer wishes to minimize total negative deviations from the gross margin expectations subject to receiving $65,000 in revenue above variable costs of production. Lowering gross margins slightly results in a considerably more diversified farm plan and substantially less risk (table 2). The MOTAD solution still contains grain sorghum (918 acres) and alfalfa (28 acres), but also contains 65 acres of cotton and 189 acres of wheat. Steers remain in the solution, but at a considerably higher level. The efficiency frontier appears to be relatively steep in the vicinity of the profit-maximizing point. Diversification of the farm plan permits the producer to receive gross margins of $65,000 while reducing the standard deviation to $36,100. The coefficient of variation (standard deviation divided by the mean) is reduced from 62.35% under the base plan to 55.54% under the first risk management scenario.

The second risk management scenario introduces the possibility of sequential marketing and forward contracting of wheat. It is on an efficiency frontier different than the first MOTAD solution for gross margins of $65,000 (table 2). The resulting farm plan contains 866 acres of grain sorghum, 156 acres of wheat, 150 acres of cotton, and 222 steers. The production from 96 acres of wheat is forward contracted in March for sale in June. Production from 60 acres of wheat is harvested in June and stored until December when it is sold. Introduction of sequential marketing and forward contracting as marketing alternatives permits the producer to reach a higher efficiency frontier. He is able to generate $65,000 in gross margins while reducing the standard deviation to $33,605. The coefficient of variation for this scenario is 51.70%.

A number of additional risk management strategies are possible. Several of the more interesting include purchase of crop insurance, cash versus crop share rental arrangements, use of the futures market for wheat and cattle, and the utilization of federal disaster payment programs. These alternatives are being explored, but time did not permit their inclusion in this paper. Instead, the analysis focuses on the feasibility of the risk efficient farm plans under alternative assumptions regarding future economic conditions—questions not easily addressed in a MOTAD framework.

Simulation Analysis

The base solution and two MOTAD risk management solutions discussed above were eval-

Table 3. Economic Situations and Strategies Evaluated in Simulation Runs for a Southwestern Oklahoma Farm

	Programming Solution									
	Base	MOTAD 1	MOTAD 2	Base	MOTAD 1	MOTAD 2	Base	Base	Base	Base
Simulation run	1	2	3	4	5	6	7	8	9	10
Percent equity	70	70	70	45	45	45	70	45	70	45
Annual percentage increase in:[a]										
Land values	7.0	7.0	7.0	7.0	7.0	7.0	4.0	4.0	7.0	7.0
Input prices	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0

[a] The following were held constant at the indicated rates of increase: output prices, 3.75%; family living, 5.0%; and machinery and building prices, 5%.

uated under alternative assumptions regarding future economic conditions. Each of these farm plans was simulated over a twenty-year period under the assumptions that the producer had a 70% beginning equity, the prices of agricultural products would increase 3.75% annually, the prices of agricultural inputs would increase 5% annually, land price would increase at an annual rate of 7%, and family living requirements and machinery and building costs would increase by 5% per year. Each of the farm plans was also simulated over a twenty-year period under the assumption that the land values increase at an annual rate of only 4%, and then under the assumption that the prices of agricultural inputs increase at an annual rate of 6%, all other rates of increase as originally specified. These simulation runs are summarized in table 3.

Table 4 presents ending net worth and farm bankruptcies for each farm plan and economic future evaluated, based on a twenty-year simulation under the indicated situation. At the end of the twenty years there would be substantial amounts of capital gains in land and capital gain taxes to be paid if the land were sold. The ending net worth has been adjusted to reflect the net that would remain after the capital gain taxes are paid, as though the land is sold in the twentieth year. The simulation model will generate cumulative probability distributions of selected variables such as net worth for use with stochastic dominance or other criteria. Only the parameters of net worth are considered here for brevity.

The expected ending net worth under each alternative is presented in the column labeled "mean" in table 4. As expected, the highest

Table 4. Ending Net Worth and Farm Bankruptcies under Alternative Farm Plans and Economic Futures, Southwestern Oklahoma Farm

Situation	Simulation Run	Ending Net Worth[a] Mean	Minimum ($1000)	Maximum	C.V.	Number of Bankruptcies
70% Equity						
Base	1	3135.7	2169.8	3856.4	9.6	0
MOTAD 1	2	3056.0	2320.9	3682.4	8.0	0
MOTAD 2	3	3099.1	2422.1	3668.6	7.3	0
Base (4% land price increase)	7	1801.2	835.4	2522.9	16.7	0
Base (6% input price increase)	9	2991.4	1899.0	3738.2	11.0	0
45% equity						
Base	4	2464.0	1185.6	3344.4	16.8	6
MOTAD 1	5	2330.7	1338.7	3137.0	15.4	2
MOTAD 2	6	2390.0	1448.8	3128.4	14.2	1
Base (4% land price increase)	8	1129.5	−148.8	2009.9	36.7	20
Base (6% input cost increase)	10	2265.2	880.1	3214.3	20.0	8

[a] Ending net worth is based on twenty years of simulated operation of the 1500-acre farm under the run situation indicated and is net of capital gains taxes on the ending value of land (payable if the land were sold).

expected net worth was obtained from the linear programming, profit-maximizing solution (run 1) where risk is assumed ignored. Simulation of MOTAD 1 (run 2) results in lower expected net worth at the end of twenty years and a reduction in the coefficient of variation. Simulation of MOTAD 2 (run 3), the solution on a higher efficiency frontier, results in slightly higher expected net worth and a lower coefficient of variation. The minimum ending net worth is higher and range of ending net worths lower for the MOTAD solutions than for the base solution which ignores risk.

Run 7 simulated the effects on the base solution of a reduction in the rate of increase in land values from 7% to 4%, other factors unchanged. The importance of land price increases on the level and stability of ending net worth is dramatically illustrated. Mean ending net worth drops from \$3.1 million to \$1.8 million and the coefficient of variation increases substantially.

The potential impact on the base solution of a change in the annual rate of increase in the cost of inputs from 5% to 6% is shown in run 9. The expected ending net worth is reduced slightly from \$3.1 million to about \$3.0 million and the coefficient of variation is increased to 11.0%. As expected, the modest increase in the price of inputs has substantially less effect than the reduction in the rate of increase in land values. No bankruptcies occurred under any of the simulation runs when the producer had a beginning equity of 70%.

When the beginning equity was reduced to 45%, the possibility of bankruptcies occurs under all five simulation runs (table 4). The relationships between and among the base, MOTAD 1, and MOTAD 2 solutions under the assumption of 45% equity (runs 4, 5, and 6) are again as expected. The base solution has the highest expected ending net worth, the highest coefficient of variation, and the possibility of six bankruptcies. MOTAD 2 has the lowest coefficient of variation and the possibility of only one bankruptcy.

A drop in the rate of increase in land values to 4% had a drastic effect at the 45% equity level (table 4, run 8). Expected ending net worth is reduced to \$1.1 million, the minimum ending net worth is negative and twenty bankruptcies occur in 100 replications. The impact of an increase in the annual cost of inputs to 6% is less severe. Mean ending net worth over twenty years is reduced only by \$200,000 and the coefficient of variation and number of bankruptcies are increased slightly compared to the base solution at 45% equity.

An approximate comparison of the results of operating the farm over twenty years under each of the plans with other off- or on-farm opportunities is obtained by deflating the ending net worth to reflect present value. The mean ending net worth for the three plans with 70% equity and base assumptions reflected about a 6% compound rate of growth. The expected rate of growth with 45% equity is approximately 5%.

Summary and Limitations

This analysis combines use of a MOTAD model to derive risk efficient farm plans and a simulation model to evaluate the feasibility of those plans under alternative economic and institutional futures. The MOTAD model demonstrates the possibility of reducing relative variability through diversification and sequential marketing and forward contracting of wheat. The simulation model calculates annual net cash income, net worth, net present value, and the chance of business failure when the risk efficient farm plans are subjected to alternative rates of increase in land values and input costs, assuming beginning equities of 70% and 45%. The chance of business failure was found to increase substantially when beginning equity is 45% and land value rises at only 4% annually.

A number of important limitations of this analysis deserve mention. First, we assumed full ownership by the farm operator. Many large commercial farms combine land ownership and rental arrangements. An earlier Oklahoma study suggests that share rather than cash rent is an effective means of spreading risk among tenant and landlord (Walker and Hardin). Farm operators might also use pasture rental arrangements or livestock shares rather than ownership of cattle to reduce their risk. On the input side, machinery rental and/or custom hiring provide input cost flexibility. The impact of these deserves additional attention.

Second, given the ownership situation, only a few risk management strategies are evaluated. On the marketing side, we have considered only sequential marketing and forward contracting. Hedging opportunities are available for both wheat and cattle, but have been ignored in this analysis. All risk crop insur-

ance is an alternative receiving current policy attention. Preliminary analysis in another Oklahoma farming area indicated that, under the insurance arrangements assumed, federal crop insurance decreased the mean income without reducing income variability (Walker and Hardin). In fact, the number of bankruptcies increased, apparently due to the annual drain on cash flows to pay premiums and borrowings to meet cash needs. Other provisions of the proposed legislation discussed by Miller and Trock could also be evaluated.

The disaster payment provisions of the current commodity programs have also been subjected to preliminary analysis revealing that disaster payments improve the income and risk performance of farms (Walker and Hardin). The only cost to the farmer is participation in the commodity programs. The disaster payment sets a lower floor on returns from the commodities covered by the program. The deficiency payment also sets a lower floor on income variability associated with price fluctuations. Other institutional arrangements deserving attention include the impact of variable interest rates and alternative forms of business organization on the ability of the farm firm to survive economic fluctuations.

References

Brink, Lars, and Bruce McCarl. "The Tradeoff between Expected Return and Risk among Corn Belt Farmers." *Amer. J. Agr. Econ.* 60(1978):259–63.

Fruend, Rudolf J. "The Introduction of Risk into a Programming Model." *Econometrica* 24(1956):253–63.

Hardin, Michael L. "A Simulation Model for Analyzing Farm Capital Investment Alternatives." Ph.D. thesis. Oklahoma State University, 1978.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1971):53–62.

Held, Larry J., and Glenn A. Helmers. "Growth, Income, and Survivorship Relationships in Wheat Farming." Paper presented at AAEA annual meeting, Blackburg, Virginia, 6–9 August 1978.

Kliebenstein, James B., and John T. Scott, Jr. *Farm Production Decision Making Using Quadratic Programming—An Empirical Application.* Agr. Econ. Res. Rep. 138, University of Illinois, April 1975.

Miller, Thomas A., and Warren L. Trock. "Disaster Assistance to Farmers—Needs, Issues, and Programs." Dep. Econ., Colorado State University, Ft. Collins, 1979.

Nieuwoudt, W. L., J. B. Bullock, and G. A. Mathia. "An Economic Evaluation of Alternative Peanut Policies." *Amer. J. Agr. Econ.* 53(1976):485–95.

Patrick, George F. "Effects of Debt Levels and Loan Arrangements on Farm Firm Survival and Growth." Paper presented at annual meeting of Western Regional Research Project W-149 Technical Committee, San Francisco, January 1979.

Schurle, Bryan W., and Bernard L. Erven. *The Return-Risk Tradeoffs Associated with Processing Tomato Production in Northwestern Ohio.* Ohio Agr. Res. and Dev. Ctr. Res. Bull. 1111, April 1979.

Simmons, Richard L. and Carlos Pomareda. "Equilibrium Quantity and Timing of Mexican Vegetable Exports." *Amer. J. Agr. Econ* 57(1975):472–79.

Walker, Odell L., and Mike L. Hardin. "Risk and Risk Control in Firm Growth—A Simulation Analysis." Paper presented to the annual meeting of the Western Regional Research Project W-149 Technical Committee, San Francisco, January 1979.

Risk Management and Risk Preferences in Agriculture: Discussion

David Bessler

I would like to commend the authors of both papers delivered in this session. The papers deal with important topics that deserve our attention. Because my major interest in this area has been the representation of economic agents' beliefs (see Bessler, and Bessler and Moore), I find it appropriate to direct the bulk of my comments to the paper delivered by Young. My comments on the paper by Mapp, Hardin, Walker, and Persaud will reflect only methodological points.

Briefly, the paper by Young reviews several empirical works on the elicitation of economic agents' risk preferences and makes certain observations on the feasibility of incorporating these preferences in various extension and research applications. The paper by Mapp et al., describes the selection of alternative risky production and management strategies using a variant of the mean-variance analysis for a southwestern Oklahoma farm operation. Outcomes from this analysis are then simulated, under alternative equity and price assumptions, over a twenty-year period.

My primary concern with both papers is that they have, for the most part, ignored the problems associated with using variance as a measure of risk and the associated stochastic dominance literature. The concern is quite real for the paper by Mapp et al., because their results are directly based on the representation of risk by variance (or an approximation of variance). My concern also applies to Young's paper. He too directs his discussion to the traditional mean-variance analysis of risky choice. Although he suggests that other procedures might apply, such as Meyer's stochastic dominance theorems, he gives only passing mention of their use in research and extension programs.

Criticisms of the mean-variance approach to analysis of risky choice have been heard for some time—probably the most elegant of these is contained in the dual papers of Rothschild and Stiglitz, written in the early 1970s. Additional work on the subject can be found in Meyer. They demonstrate that the ordering among risky prospects using the mean-variance approach is not necessarily equivalent to that obtained using three alternative rules for ordering. These three alternatives are, however, consistent among themselves. It is, for instance, quite easy to construct reasonable looking utility functions and probability distributions for two risky prospects, say F and G, for which F has a larger mean and a smaller variance than G, and yet have G be preferred to F. The idea is to make G highly skewed to the right.

I refer to these deductive arguments not to suggest that the results of Mapp et al., are necessarily invalid, for my degree of belief would suggest they are valid ($p = .80$). However, the deductive arguments do suggest certain empirical questions which should be answered before we go further with this type of analysis.

The questions involve the measurement of the probability distributions and utility functions relevant for choice among a particular set of risky actions. If the subjective probability assessments of the particular group of economic agents are normal or if their elicited utility functions are quadratic in income (wealth), then the procedures used by Mapp et al., are proper. If both of these conditions do not hold, then I suggest the more general stochastic dominance theorems be applied. This latter course is less desirable because pair-wise comparisons among distributions must be made—this is operationally tedious. Nevertheless, there have been numerous applications of these procedures in the literature (see Anderson et al.).

The paper by Young investigates the measurement of risk preferences. His findings, especially those related to Binswanger's work, are important and should not be taken lightly. The major point which Young's paper brings

---

David Bessler is an assistant professor in the Department of Agricultural Economics at Purdue University.

out of Binswanger's work is the proper one—that is, elicitation procedures carried out with hypothetical rewards and in brief sessions can yield incorrect results. More generally, one might say that we have not had very good experimental controls in much of our past work on utility elicitations. The use of rewards as a control (or assessor motivation) is not new in the general assessment literature. In fact, their use and advantages have been major points of study in the area of probability assessment for some time (see Winkler). However, I have not run across their direct use in utility assessment. Nevertheless, their use should be considered in both probability and utility assessment work.

The fact that Binswanger made multiple elicitations from the same assessor over several weeks is also commendable.

The concern Young shows on the added cost to research from paying assessors is quite real. Yet, if the "interview" method of elicitation does perform so poorly, and if we believe the research we undertake is important, then hundreds of thousands of dollars spent to obtain micro-observations should not necessarily be out of line. On this point I borrow the words of Juster:

> Economists are not accustomed to thinking in terms of these orders of magnitude (millions of dollars), but I suggest we take a page from the books of our brethren in the physical sciences. Particle accelerators and astronomical observatories that cost in the tens of millions are not uncommon, and they are judged to be worth their cost. Yet one is simply a way to generate observations, and the other is a way to measure observable physical phenomena. (p. 15)

Because most of our training and research involves the use of secondary data (designed for purposes not necessarily related to our research), we frequently are able to write project statements with relatively low data collection costs. A project requiring large control expenditures for data collection will most probably be judged extravagant when compared with projects not using these controls. Thus, Binswanger's documentation on the needs for these control expenditures (and Young's bringing it to our attention) is an important bit of information.

I would now like to raise a few specific points on these papers.

Mapp et al., continue to make the distinction between risk and uncertainty. By now, the reader has probably observed that I approach risk analysis from a subjective view. Thus, I find that this distinction is not very meaningful. Given the weight of other authors who sit in the subjective camp, I am curious why these authors continue to make the distinction. What type of analysis would the authors suggest if no exchangeable observations were available upon which to base their probabilities?

Mapp et al., use the triangular distribution to represent the probability distributions of each production activity. I find this representation to be interesting. However, I suspect that in some cases it may misrepresent the tails of the distributions rather severely—especially since the representations are based on only 13 observations. As an extension of their work, it would be interesting to compare these modeled representations with elicited subjective distributions from a sample of southwestern Oklahoma farmers.

The recommendation by Young that we report alternative decision options and their objective outcome probabilities is at first glance a laudable recommendation. However, further study might suggest that markets may already be reporting these options. Before public sector reporting is undertaken, it is necessary to better document its need and value. It is my guess that for many commodities, existing markets do a fairly good job of providing this information. That is, I suspect that market participants are, quite often, very much aware of relevant options and the probability distributions associated with the consequences of selecting any particular one. This point is generally an application of Muth's rational expectations hypothesis. More specifically, before we undertake a project of reporting options and objective outcomes, we must demonstrate that existing private markets are in some way failing to provide this information. Of course, where market failures in providing this information occur, I support Young's recommendation.

References

Anderson, J., J. Dillon, and J. Hardaker. *Agricultural Decision Analysis*. Ames: Iowa State University Press, 1977.

Bessler, D. A. "Foresight and Inductive Reasoning: An Analysis of Expectations on Economic Variables by California Field Crop Farmers." Ph.D. thesis, University of California-Davis, 1977.

Bessler, D. A., and C. V. Moore. "Use of Probability Assessments and Scoring Rules for Agricultural Forecasts." *Agr. Econ. Res.* in press.

Juster, F. T. "Microdata Requirements and Public Policy Designs." *Ann. Econ. and Soc. Measure.* 1(1972):7–16.

Meyer, J. "Stochastic Dominance, Increasing Risk, and Risk Aversion." Institute for Mathematical Studies in the Social Sciences, Work. Pap. 45, Stanford University, July 1974.

Muth, J. "Rational Expectations and the Theory of Price Movements." *Econometrica* 29(1961):315–35.

Rothschild, M., and G. Stiglitz. "Increasing Risk: I. A Definition." *J. Econ. Theory* 2(1970):255–43.

Rothschild, M., and G. Stiglitz. "Increasing Risk: II. Its Economic Consequences." *J. Econ. Theory* 3(1971):66–84.

Winkler, R. "Probabilistic Prediction: Some Experimental Results." *J. Amer. Statis. Assoc.* 66(1971):675–85.

Risk Management and Risk Preferences in Agriculture: Discussion

Thomas A. Miller

These papers indicate that the process of individual decision making under risk is at least conceptually clear. When faced with risky situations, farmers choose risk management strategies based on their appropriate risk preferences. Unfortunately public decision making about agricultural risk management is not this well developed. Issues concern both what public risk management programs are needed for agriculture and the likely impacts of such programs. The papers presented here contain a number of intriguing implications about public risk management issues in agriculture, even though they do not directly address these issues. I will focus my remarks on these implications instead of making a detailed review or criticism of the papers.

Agricultural risk is a factor in two important groups of policy issues. One concerns Federal Crop Insurance and disaster payments. At the Western Agricultural Economics Association (WAEA) meetings last year, I discussed the issues concerning the government's role in providing disaster assistance to farmers (Miller and Trock). The U.S. Congress still is debating this question and appears moving toward a greatly expanded federal crop insurance program with some public subsidy to reduce farmer premiums. Answers to questions concerning both farmer needs for this assistance and its structural impacts are critically important if rational economic decisions are to be made on this program.

A second group of policy issues that are related to risk concern the structure of agriculture. Here the policy debate is not cast in terms of risk; it concerns family farms, the structure of agriculture, and the impact of policy on this structure. But risk may be one of the key mechanisms that links policy and structural change. The current U.S. farm programs assume risk through income support and grain reserve provisions, as well as through disaster payments and crop insurance. Raup recently observed that the federal assumption of agriculture risk is the single most pervasive example of how federal policies affect land use—how it is used, where it is used, and who uses it. Others have argued that the risk assumption effect of government commodity programs is a major policy influence on the structure of agriculture—possibly towards large scale, single purpose, nonfamily farms (Pope and Gardner, Sharples). Young cites other studies that suggest the opposite effect.

Simply put, the issues are these. What is the proper sharing of agricultural risks between the public and private sectors? Does federal assumption of agricultural risk have unexpected structural impacts? Do the likely benefits of such programs justify the costs, both public and private? I would like to discuss the papers presented here from the perspective of what they imply toward these issues.

Young has argued that the consideration of producer risk preferences may be necessary to understand thoroughly the consequences of public policies to mitigate instability. While traditional risk-neutral profit-maximization assumptions may be adequate for many research studies, the analysis of the distributive impacts of risk-modifying policies may require reliable risk preference measurements for appropriate groups of farmers. Two groups of hypotheses are of interest here: (*a*) the relationship between producer risk preferences and structural features, especially farm size and the legal form of ownership; and (*b*) the relationship between accounting measures of financial ability to bear risk and the willingness to bear risk. Testing these hypotheses is necessary to undestand the "dynamic structural implications" of public policies to mitigate income instability in agriculture.

Young's paper, therefore, has implications for both groups of policy issues I described at

---

Thomas A. Miller is with the National Economics Division, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, stationed at Colorado State University.

The views expressed here do not necessarily reflect the position of the U.S. Department of Agriculture.

the outset. Research on the risk preferences of different groups of farmers would increase our understanding of the impact and need of public disaster assistance programs. And because risk apprarently links policy to structure, measurement of risk preferences among different categories of farmers may also be of assistance in developing an effective structures policy for American agriculture.

While not explicitly requiring the measurement of risk preferences, the Mapp et al. paper describes a methodology for analyzing the impact of federal risk assumption programs at the individual farm level. The methodology encompasses much of the complexity of decision making under risk and provides one means of testing some of the hypotheses identified in the Young paper. I encourage the authors to evaluate additional public-supported risk management strategies including all risk crop insurance, hail insurance, direct disaster payments under the commodity programs, and the deficiency payments provided by the current target price mechanism.

The direct results of the Mapp research are consistent with the theory of decision making under uncertainty. Enterprise diversification is an effective risk management strategy. But this strategy, as well as other risk management tools, generally involves an income sacrifice. A farm operator's equity is extremely important in his ability to bear risk and in the long-run ability of the farm to survive and maintain profitability. A continued increase in land values is an important factor allowing farmers to bear risk, due to its favorable impact on equity ratios. Relative stability in input prices is of lesser importance. These preliminary results appear reasonable and suggest numerous additional questions to be analyzed.

Considered together, the two papers provide a number of interesting ideas concerning the impact of federal risk assumption programs. Since some of these relationships do not have a strong empirical basis at this time, it is convenient to describe them as hypotheses for further research.[1] Five major hypotheses cover both natural disaster assistance programs and commodity programs that decrease price and income variability: (*a*) Public risk assumption programs decrease the need for farm enterprise diversification and thus encourage more highly specialized farming operations. (*b*) Public risk assumption increases farm income slightly by decreasing the need for risk management strategies that would otherwise involve a farm income trade-off. (*c*) Public risk assumption programs enable farms to operate at lower equity levels by limiting the bankruptcy risk of highly levered financing. The implications of this hypothesis need to be carefully considered since the social cost of individual farm bankruptcy is unclear, particularly if such farms fail because they are poor risk managers. (*d*) Public risk assumption encourages the flow of outside funds into agriculture, increases the means of farms to grow, and increases the returns of capital relative to management. (*e*) Federal risk assumption encourages large-scale, specialized, low-equity farms financed from outside agriculture—and lessens the comparative advantage of traditional moderate-sized, diversified owner-operated family farms.

I believe that these hypotheses are among the most important that our profession can investigate. Do the likely benefits of public risk assumption programs justify the public cost and the possible structural impacts? The two papers just presented provide us with a basic theory and an operational methodology for testing these and other hypotheses. The future prospects for work in this area are both relevant and exciting.

[1] I have made on additional assumption in stating these hypotheses—that many farmers are already using prudent risk management strategies such as the ones evaluated by Mapp et al.

References

Miller, Thomas A., and Warren L. Trock. *Disaster Assistance to Farmers—Need, Issues, and Programs.* Great Plains Agricultural Council Pub. No. 88, Colorado State University, Feb. 1979.

Pope, Rulon D., and B. Delworth Gardner. "The Structure of Agriculture and Risk." *Market Risks in Agriculture: Concepts, Methods, and Policy Issues*, ed. P. Berry. Texas Agr. Exp. Sta. DTR-78-1, July 1978.

Raup, Philip M. "The Federal Dynamic in Land Use." Paper presented at the meeting of the Committee on Long-Range Land-Use Planning, National Planning Association, Washington, D.C., 31 May 1979.

Sharples, Jerry A. "Price and Income Supports: Impacts on Structure." Mimeographed. Purdue University, 13 July 1979.

Risk Management and Risk Preference in Agriculture: Discussion

Steven T. Sonka

As evidenced by recent events, uncertainty about the future has seemingly become a characteristic of American society (Bazelon). The agricultural producer, of course, is subjected to those societal risks but, because of the particular aspects of agricultural production, uncertainty about future outcomes is a more critical concern for these producers. Therefore it is quite appropriate for agricultural economists to select this topic for discussion at these meetings. Although the two papers both address the risk question, the research topics they address have a considerable divergence. In part, of course, this only reflects the different orientations in which agricultural economists view the risk problem area.

Risk Preference

The paper by Young is primarily directed toward the problem of measuring producer's risk preference. Given the standard introductory comments we all make as to the importance of risk for the farmer, the investigation of farmer risk preferences would appear to be a high priority research need. However, for reasons detailed later, reflection and expansion on the issues reviewed by Young lead me to suspect that this research area may not have as high a payoff as it, at first glance, would appear.

Young's compilation of evidence as to risk preferences, which is a culmination of an extensive effort (Young et al.), is a useful statement of our present empirical knowledge base. And I concur with his concern about the validity of risk assessments generated from the direct elicitation and experimental methods.

A major strength of Young's paper, in my opinion, is its final section. In that section the question is asked, "What would we do with these coefficients even if we could estimate them?" This is a most useful question, although many of us may be guilty of not often asking it relative to our own research. Of the three uses suggested, the paper's discussion indicates that the microeconomic policy and predictive applications area has the most potential for utilizing risk aversion parameters.

But would the availability of risk aversion parameters really help us accomplish better policy and predictive work? Although risk is often an important factor which might encourage a decisionmaker to select a nonprofit-maximizing alternative, it certainly is not the only force which may temper the profit criterion.

For example, for several years Reiss has informally interviewed purchasers of farmland as to their reasons for buying land. Some of the motives cited relate to the income potential of the purchased property. However, several do not. Factors such as a son returning to the farm, a desire to own land, or the need for the house on a particular property were also cited as major reasons for buying farmland. Two additional factors often cited were tenure security and hedging against inflation. Although these latter two factors relate to uncertainty they are not captured by a risk aversion coefficient relating to variability of annual income flows (Harris and Nehring). But these variables do affect the bid price of individuals attempting to purchase farmland.

Therefore if we want to predict future behavior it may be as or more important to attempt to model the influence of these multiple objectives as it is to measure risk preferences. This comment supports Young's recommendation to bypass direct estimation of formal risk aversion coefficients, although possibly for differing reasons. It is important that our attempts to model the effects of uncertainty do not lead to our ignoring the effects of other important behavioral attributes of the farm decisionmaker.

Steven T. Sonka is an associate professor in the Department of Agricultural Economics at the University of Illinois.

Analysis of Risk Management Strategies

For farm management recommendations, however, it may often be quite useful to analyze alternatives in terms of their impact on income variability. The research summarized in the Mapp et al. paper utilizes such an approach. They first evaluate risky alternatives considering both expected income and returns variability using a MOTAD programming model. By parameterizing expected returns, they can then trace a curve analogous to an *E, V* frontier for several alternatives (Scott and Baker).

A major strength of their research effort is that they do not terminate their analysis at this point. Instead, by combining the attributes of two modeling techniques, the characteristics of their risk efficient plans can be evaluated in terms of outcomes, i.e., change in net worth and probability of bankruptcy, which have meaning for farm decisionmakers.

The research potential exhibited in the paper is impressive. The attainment of this potential should be applauded and might serve as a model for other groups of researchers concerned with generating information relevant to problem solutions.

On a negative note however, the alternatives analyzed in this paper are rather unexciting. Although the strategies discussed do exhibit the potential of their research approach, several of the risk management strategies cited as candidates for further research, such as crop insurance, nontraditional financing arrangements, and leasing alternatives, would be markedly more interesting than those presented.

Both the Young and Mapp et al. papers address research concepts which are important to researchers concerned with the impact of uncertainty on agricultural producers. Both should be interesting and thought-provoking readings for agricultural economists interested in doing research in the risk area.

References

Bazelon, D. L. "Risk and Responsibility." *Science* 205(1979):277–80.

Harris, D. G., and R. F. Nehring. "Impact of Farm Size on the Bidding Potential for Agricultural Land." *Amer. J. Agr. Econ.* 58(1976):161–69.

Reiss, F. J. "Decision Making in the Farmland Market." *J. Amer. Soc. Farm Mgrs. and Rural Appraisers*, no. 2(1976), pp. 35–43.

Scott, J. T., Jr., and C. B. Baker. "A Practical Way to Select an Optimum Farm Plan under Risk." *Amer. J. Agr. Econ.* 54(1972):657–60.

Young, D., W. Lin, R. Pope, L. Robison, and R. Selley. "Risk Preferences of Agricultural Producers: Their Measurement and Use." *Proceedings of 1979 Meeting of Western Regional Project W-1419.* Dep. Agr. Econ. 4478, University of Illinois.

Capital Gains versus Current Income in the Farming Sector

Emanuel Melichar

The value of farm assets has increased in most years since the Great Depression, mainly because of rising farm real estate prices. After 1970, annual increases in asset values have each year exceeded annual net farm income (including landlords' net rent), often by wide margins.

This paper examines the magnitude and causes of asset appreciation. It first notes that asset appreciation should be adjusted for general price inflation before it is compared with income. The comparable series, known as real capital gains, has been roughly equal to net farm income during this decade. Next, the primary origin of these significant real capital gains is traced to the fact that, contrary to the popular impression, the current return to farm assets has grown rapidly over the past twenty-five years, even when measured in constant dollars. It is then shown that, according to asset-pricing theory, a farm economy characterized by rapid growth in the real current return to assets will tend to experience large annual real capital gains and a low rate of current return to assets—which corresponds to actual experience in most years since the mid-1950s. This inescapable tendency has serious and paradoxical implications for the structure of agriculture and for farm policy, which are briefly sketched in the concluding remarks.

Capital Gains

At the aggregate sector level, analytical work on increased asset values as a form of return to farming seems to have been stimulated by Hathaway's 1957 observation that significant asset value increases were occurring in most years, and in particular by his technical error in adding asset value increases to net income and publishing the total.

The work that followed thus focused on constructing series that validly could be compared with net income. In the early 1960s, Grove first pointed out that annual net investment in farm assets should have been subtracted, and then Hoover and Boyne independently noted the further need for including gains or losses, on both assets and debt, resulting from changes in the general price level. Since the series constructed by Hoover and by Boyne included gains or losses on the purchasing power of funds owed to others, they could not be called "asset price appreciation"; their authors labelled them "real capital gains." The real capital gains series were next discussed and updated by Bhatia in 1971, and more recently by Brake and Melichar (pp. 445–47) and by Melichar and Sayre (1975, 1977).

Real capital gains are here computed as outlined by Melichar and Sayre (1977, pp. 58–62). First, total net investment and net transfers into the farming sector are subtracted from the annual change in the value of physical assets. This step yields the series known as "nominal capital gains." In the upper panel of figure 1, nominal capital gains are compared with income in a chart similar to that published annually by the U.S. Department of Agriculture (USDA; Evans, p. 17). As already noted, however, this comparison is misleading. If all of net farm income is transferred out of the farming sector (for instance, spent for con-

---

Emanuel Melichar is a senior economist with the Division of Research and Statistics, Board of Governors of the Federal Reserve System, Washington, D.C.

The analyses and conclusions are those of the author and do not necessarily reflect the views of the Board of Governors or the other members of its staff.

Advice and data on asset values and the return to assets received over a period of years from Carson Evans and Bruce Hottel, ESCS, U.S. Department of Agriculture, are much appreciated by the author. Balance sheet and income data used here are available from ESCS as of July 1979, except that farm income data for 1979 are projected by the author.

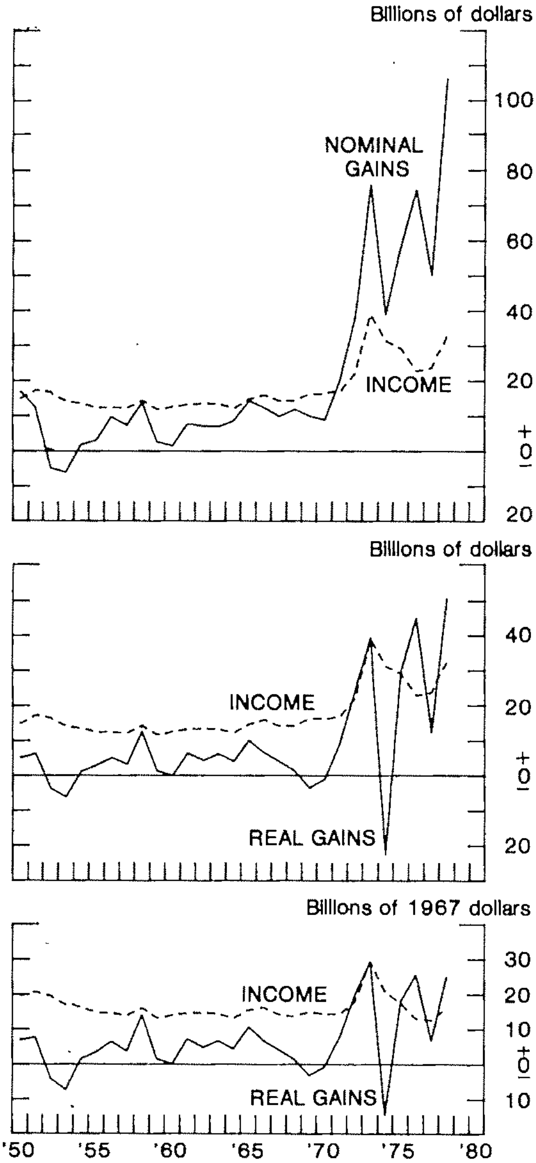


Figure 1. Capital gains compared with net farm income

sumer goods or nonfarm investments) the real wealth position of the sector is not changed. In a time of general price inflation, that also holds for real capital gains, but not for nominal gains.

Real capital gains are computed by adjusting the nominal gains for the gains or losses resulting from each year's change in the purchasing power of the funds tied up in assets or of the funds owed. These adjustments have been huge for recent years of rapid general price inflation. In 1978, for example, nominal capital gains of $106 billion were experienced on assets valued at $713 billion on 1 January. But general price inflation of 9.3% resulted in a purchasing power loss of $67 billion on assets held (9.3% of $713 billion) and a purchasing power gain of $11 billion on debt owed (9.3% of $119 billion).

The final result, real capital gains, is shown in the middle panel of figure 1. In most years, farm real estate has been the primary source of real capital gains and losses. However, cattle price changes contributed large losses in 1952 and 1974 and large gains in 1958 and 1978. Farm debt also has become a significant source of real capital gains, partly because of its rapid growth, but mainly because of more rapid general price inflation. Over two decades preceding 1972, real capital gains averaged about one-third as large as net farm income. Since then, on average, income and real gains have been roughly equal.

To compare recent capital gains (or income) with those of earlier years, it is advisable to express the data in terms of dollars with the same purchasing power, as in the lower panel of figure 1. Even in constant dollars, recent real capital gains are on average significantly larger than in earlier periods.

Origin of the Real Capital Gains— The Current Return to Assets

Many of the policy implications of large annual real capital gains depend on the cause of those gains. It is important to know, for instance, whether real capital gains are occurring because the return to assets is rising or because of some other influences.

The return to farm assets has been growing rapidly over the past twenty-five years; in fact, the return has risen somewhat faster on average than either farm real estate prices or the total value of farm assets (Melichar 1978). The common impression to the contrary has arisen through use of an inappropriate measure of the return to assets.

Typical discussions of land prices have proceeded by stating that, in theory, land prices should be related to "income." They then go on to compare operators' net farm income with the USDA index of farm real estate value per acre. Land prices have tended to rise faster than such income, especially prior to 1968. By that time this concept had become entrenched in much analytical thinking and literature.

There are, however, important defects in-

herent in comparing operators' net farm income with land prices. To begin with, an aggregate return is being compared with a unit price; moreover, the aggregate income is being regarded as a return to real estate alone, ignoring other productive assets. These defects can be remedied by replacing the real estate price index with the aggregate USDA series called "farm production assets" (Evans, p. 15).

Furthermore, operators' net farm income is not an appropriate measure of the return to either land or production assets. First, because a significant portion of farm real estate is owned by nonoperator landlords, their net rental income should be added. Interest paid on farm debt should also be included, as the goal is a return to assets rather than to equity. And, since farm production assets exclude operators' dwellings, that part of operators' net farm income consisting of the imputed return to the equity in these dwellings should be subtracted.

The series derived after making these adjustments is charted as the topmost curve in figure 2. However, as its title indicates, it remains a return not only to assets but also to management and to operators' labor. Thus, over time, comparisons between it and asset values may be distorted by changes in the relative importance of assets, management, and operators' labor in farm production. In view of the well-known reduction in operator numbers and man-hours, often described as "the substitution of capital for labor," one should not be surprised to find that this series is not an appropriate indicator of trends in the return to assets alone.

The upper panel of figure 2 shows the decomposition of the total return, as estimated by the USDA (Evans, p. 16). The lower panel, which shows the percentage distribution each year of the same three components, helps to clarify the significant change that occurred. Over the last twenty-five years, the proportion of the total return that could appropriately be ascribed to operators' labor has dropped from 63% to 17%, while the proportion that could be regarded as a return to production assets has risen from 25% to 69%. Consequently, as shown in the upper panel of the chart, the

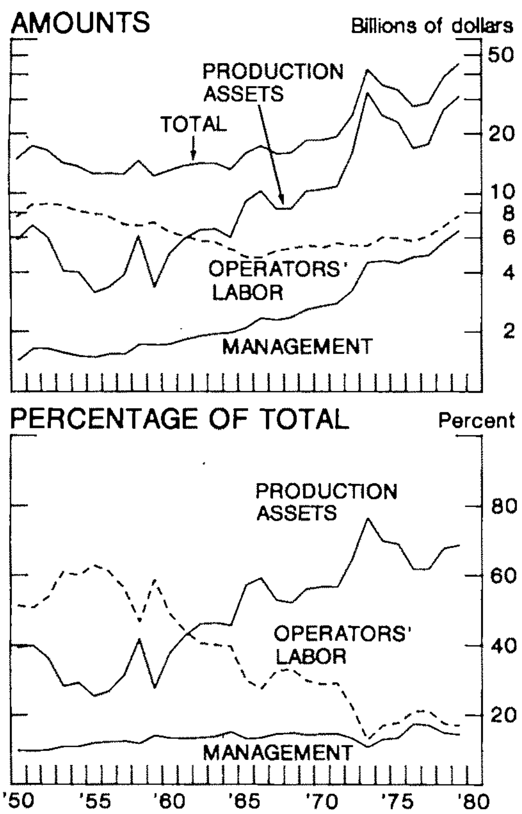


Figure 2. Distribution of the total return to pro duction assets, management, and operators' labor

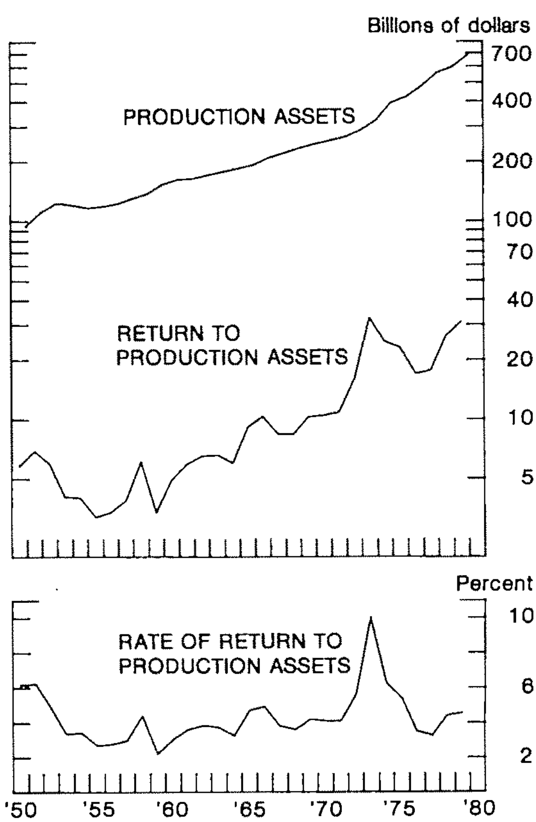


Figure 3. Residual return to production assets compared with value of such assets

estimated return to farm production assets has risen very rapidly over this period.

Figure 3 shows the residual return to farm production assets, the value of these assets, and—in the lower panel—their ratio, the rate of current return to such assets. It is evident that a markedly different picture of relative trends in asset values and returns has emerged. Since the mid-1950s, the return to farm production assets has risen faster than the value of such assets. Thus the rate of return rose from an average of 3.0% in 1955–59 to 4.2% in 1965–69, and again averaged 4.2% in 1975–79 in spite of the slump in 1976 and 1977.

Given the growth exhibited by the return to assets and the dominant position of farm real estate among these assets, there is no question but that farm real estate prices had to rise significantly. For instance, if farm real estate prices had remained at their 1954 level while the return to assets rose as it actually did, the rate of current return to assets in 1978 would have been 12% rather than the actual figure of 4%. Thus growth in the current return has figured prominently in upward pressures on land prices and hence in the occurrence of real capital gains. The arithmetic of this relationship is the next topic.

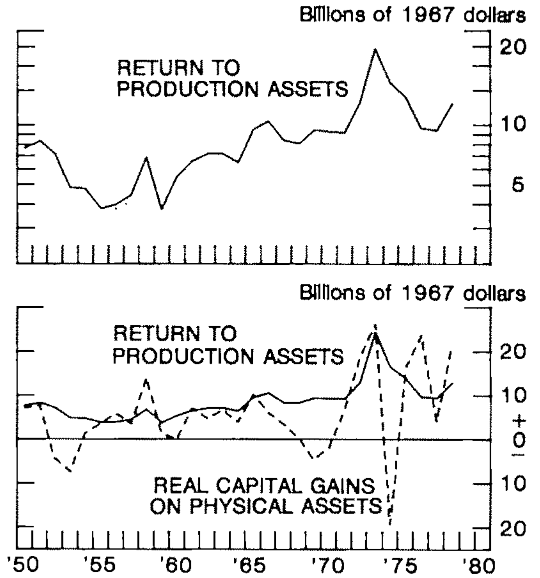


Figure 4. Return to assets compared with real capital gains, in 1967 dollars

Theoretical and Empirical Relationships Among Current Return, Capital Gains, and Assets

Key results of the first two parts of this paper are brought together in figure 4. The upper panel demonstrates that the constant-dollar current return to farm assets has exhibited significant growth since the mid-1950s. Its annual growth rate over the period 1954–78 averaged 4.25%.

In the lower panel of figure 4, annual real capital gains on physical assets are compared with the annual current return to production assets. When discussing real capital gains as a form of return to assets, it is more meaningful to compare them with the current return to assets than with total net income which, as already shown, contained a much greater proportion of labor income in earlier than in more recent years. Note that real capital gains on physical assets were on average nearly as large as the current return from 1954 through 1967 as well as in the 1970s.

In table 1, average values of these data are shown for four periods into which the past twenty-five years have been divided on the basis of differences either in the growth rate of the current return, shown in column A, or in the relative importance of real capital gains, shown in column C. In addition, column B shows the average rate of current return, and column D shows a measure of the average annual real percentage change in farm real estate prices.

For insights into the historical experience and relationships summarized in table 1, it is instructive to examine parallel relationships inherent in the asset-pricing model for an asset with a growing return. In its simplest form (ignoring complications such as inflation and taxes), the formula that relates the equilibrium present value of such an asset to its return is

$$V = \frac{1+g}{1+d} R + \frac{1+g}{1+d} V,$$
$$= \frac{1+g}{d-g} R,$$

where V is the present value of the asset, R is the present current return, g is the annual growth rate of the current return, and d is the discount rate applied to future returns.

For this asset, real capital gains arise in two different ways. First, changes in the value of R, g, or d result in a new equilibrium value V, and the amount of change in V is a real capital gain. Second, if the growth rate g is greater than zero, the equilibrium value V rises each

Table 1. Summary of Historical Constant-Dollar Relationships among Current Return, Capital Gains, and Asset Values, for Selected Periods

Period	Average Annual Growth Rate of Current Return to Production Assets (%)	Average Annual Rate of Current Return to Production Assets (%)	Average Annual Real Capital Gains on Physical Assets as Percentage of Current Return	Average Annual Real Capital Gains on Real Estate as Percentage of Real Estate Assets
	(A)	(B)	(C)	(D)
1954–60	2.4	3.1	91	3.1
1961–67	6.2[a]	4.0	76	3.5
1968–71	2.3[a]	4.0	2	−0.2
1972–78	5.0[a]	5.4	91	4.9

[a] Growth rate from return in year preceding period shown to return in last year of period.

year even though the values of g and d are unchanged; that is, annual real capital gains are an inherent feature of the equilibrium condition.

Panel A of table 2 helps to illustrate the first source of real capital gains. For instance, at a discount rate of 6%, an asset whose return is growing at a rate of 1% annually will tend to be priced at 20.20 times its current return. If the growth rate of the return rises to 2%, the equilibrium multiple rises to 25.50. Thus this change in the underlying conditions causes equilibrium asset value to rise by 5.30 times a single year's current return. If the asset market should recognize and "discount" this growth rate change within one year, the real capital gain recorded that year would dwarf current income in that year. Suppose, however, that the asset market were to take five years to become fully aware of this growth rate change. In each of these years, the ongoing revaluation of the asset would on average result in real capital gain roughly equal to the current return. In the sixth year, the new equilibrium asset value having been reached, real capital gains from this source would vanish. This could come as a shock to analysts who had projected future gains primarily on the basis of the past record of such gains.

Revaluations of this kind are always going on in asset markets. In any historical record of real capital gains, an unknown proportion consists of gains of this essentially temporary and reversible nature.

The last three panels of table 2 help to clarify the second kind of real capital gains, those that occur annually in an equilibrium situation.

Panel B shows that, at equilibrium, the annual rate of increase in the price of an asset is equal to the growth rate of the annual return. For instance, if the equilibrium price of an asset this year is 25.50 times earnings and those earnings are rising by 2% annually, then next year, when those earnings are 2% higher, the asset is again priced at 25.50 times earnings and thus its price is also 2% higher. Therefore the value of the asset grows at the same rate as its return.

Panel C shows the equilibrium rate of current return at various combinations of the growth and discount rates. Note that the sum of the rate of current return (in panel C) and the rate of capital gains (in panel B) is equal to the discount rate. But since the growth rate is the same as the rate of capital gains, it is also evident that the rate of current return is equal to the discount rate minus the growth rate. In other words, the discount rate determines the total rate of return, and the growth rate determines how that total return is divided between a capital gain and a current return.

Suppose that one has an asset whose current return is growing at 2% annually, and that the discount rate of participants in the market for that asset is 6%. Panel C shows that the asset will be priced to yield an annual current return of 4%. For this asset, therefore, the ratio of annual capital gains to current return will be 2/4; that is, each year capital gains will be equal to 50% of current income. This result, shown in panel D, is simply the figure in panel B expressed as a percentage of the corresponding figure in panel C.

Upon scanning panel D, it becomes evident that substantial annual capital gains are inherent in equilibrium situations characterized by growth rates such as those recorded in table 1. In returning to table 1 to make such a comparison of historical and equilibrium capital gains,

Table 2. Equilibrium Constant-Dollar Relationships among Current Return, Capital Gain, and Asset Value, at Various Growth and Discount Rates

Annual Growth Rate of Current Return to Assets (%)	Discount Rate Applied to Future Returns (Required Rate of Return to Assets) (%)											
	1	2	3	4	5	6	7	8	9	10	11	12
	A. Equilibrium Asset Value per $1.00 of Current Return ($)											
0	100.00	50.00	33.33	25.00	20.00	16.67	14.29	12.50	11.11	10.00	9.09	8.33
1		101.00	50.50	33.67	25.25	20.20	16.83	14.43	12.62	11.22	10.10	9.18
2			102.00	51.00	34.00	25.50	20.40	17.00	14.57	12.75	11.33	10.20
3				103.00	51.50	34.33	25.75	20.60	17.17	14.71	12.88	11.44
4					104.00	52.00	34.67	26.00	20.80	17.33	14.86	13.00
5						105.00	52.50	35.00	26.25	21.00	17.50	15.00
6							106.00	53.00	35.33	26.50	21.20	17.67
7								107.00	53.50	35.67	26.75	21.40
	B. Annual Capital Gain as a Percentage of Asset Value											
0	0	0	0	0	0	0	0	0	0	0	0	0
1		1	1	1	1	1	1	1	1	1	1	1
2			2	2	2	2	2	2	2	2	2	2
3				3	3	3	3	3	3	3	3	3
4					4	4	4	4	4	4	4	4
5						5	5	5	5	5	5	5
6							6	6	6	6	6	6
7								7	7	7	7	7
	C. Annual Current Return as a Percentage of Asset Value											
0	1	2	3	4	5	6	7	8	9	10	11	12
1		1	2	3	4	5	6	7	8	9	10	11
2			1	2	3	4	5	6	7	8	9	10
3				1	2	3	4	5	6	7	8	9
4					1	2	3	4	5	6	7	8
5						1	2	3	4	5	6	7
6							1	2	3	4	5	6
7								1	2	3	4	5
	D. Annual Capital Gain as a Percentage of Annual Current Return											
0	0	0	0	0	0	0	0	0	0	0	0	0
1		100	50	33	25	20	17	14	12	11	10	9
2			200	100	67	50	40	33	29	25	22	20
3				300	150	100	75	60	50	43	38	33
4					400	200	133	100	80	67	57	50
5						500	250	167	125	100	83	71
6							600	300	200	150	120	100
7								700	350	233	175	140

it would be futile to assume and misleading to imply that any past period represented equilibrium. But the comparison does show that the substantial real capital gains experienced over most of the past twenty-five years—no matter what their origin—were on the whole no greater than those that would have been expected to occur at equilibrium, given the growth rates exhibited by the current return to production assets.

At equilibrium, the percentage that the growth rate in column A of table 1 is of the rate of return in column B would be equal to the percentage in column C. The actual relative amount of capital gains shown in column C is slightly above such an equilibrium level in the 1950s, considerably below it during the next two periods, and about equal to it during 1972–78.

Alternatively, at equilibrium, the percentage gains in column D of table 1 would be equal to the growth rates in column A. Again, the historical gains were slightly higher in the 1950s, much lower in the 1960s, and about the same in the 1970s.

It thus appears that both recent real capital gains and those of 1954–67 are, in a sense, fully explained by the growth exhibited by the current return to assets. Changes in other land market influences, such as nonfarm demand

and the discount rate, therefore appear to have largely offset one another.

Implications for Agricultural Structure and Policy

The foregoing rates and relationships have serious implications for the structure of the farming sector and for public farm policy. Given a growth rate of 4% to 5% in the constant-dollar current return to assets, the farming sector is doomed, at likely discount rates, to a relatively low rate of current return on the market value of assets. This inescapable consequence is the common root of many of the farming sector's current problems: cash flow difficulties; large increases in debt; troubles of beginning farmers; the attraction of farm real estate for persons of large wealth or high income—all of these stem from the fact that, at such a growth rate, a significant proportion of the total return to farm real estate necessarily takes the form of real capital gains. To borrow the language of the stock market, farm real estate is a "growth stock," best and most easily owned by those who can tolerate its low current return in the first few years after its purchase.

In attempting to respond to cash flow problems and the like, it might appear logical to take policy actions that increase the growth rate of the current return. However, the principal longer-term effect of programs that maintain or increase the growth rate is not on the profitability of farming, but rather on the degree to which profit takes the form of capital gains rather than current return. Policy actions that increase the growth rate will tend to depress the rate of current return to assets, and thus the problems they seek to address are eventually aggravated. The implications of capitalization of an increased growth rate in income are therefore more severe than those of the well-known "capitalization of an increase in income."

A low current return to the market value of assets is not a problem for all farmers. Established farmers, like wealthy stockholders, thrive on the growing and eventually high rates of return on the funds invested in earlier years. But persons of limited means find it difficult to undertake investments with a low initial current return—or may find themselves in financial difficulty shortly after doing so. In the interests of preserving or promoting certain characteristics of the structure of farming, it may be considered desirable to assist these persons in making or in surviving such investments. It is evident that such aid should be provided in ways that do not tend to increase further the growth rate of the current return in farming generally; otherwise, a few years later new entrants are likely to face still lower rates of current return.

There are parallel implications for other aspects of farm policy. Designers of farm programs should bear in mind that, over time, the rate of current return to assets is inversely related to the growth rate of that return. Thus, for instance, programs to reduce the short-run variability of income may need to truncate peaks as well as troughs of farm output prices and to adjust constant-dollar commodity support levels downward as productivity advances; otherwise, their unintended long-term effect may be to reduce the rate of current return.

More generally, farm land price research needs to be reexamined in the context of the foregoing framework. Among the variables popular in recent models, "net farm income" seems clearly inappropriate, while the role and interpretation of "expected capital gains" and perhaps also "current yields on alternative investments" needs to be reconsidered. The present rate of current return (and thus the present level of land prices) appears implicitly indicative of expectations that the constant-dollar return to assets will grow at an average annual rate of perhaps 5% over a lengthy future period. Earlier studies have indicated that technological advances in combination with government commodity programs that maintained output prices were instrumental in establishing a growing real return to assets (Brake and Melichar, p. 442). In this decade, increased foreign demand in concert with government programs appears to have been the primary factor maintaining or increasing the growth rate of that return. Renewed study of these relationships should further advance understanding of past and probable future land price trends.

References

Bhatia, Kul B. "On Estimating Capital Gains in U.S. Agriculture." *Amer. J. Agr. Econ.* 53(1971):502–6.

Boyne, David H. *Changes in the Real Wealth Position of Farm Operators, 1940–1960*. Michigan State University Agr. Exp. Sta. Tech. Bull. 294, 1964.

Brake, John R., and Emanuel Melichar. "Agricultural Finance and Capital Markets." *A Survey of Agricultural Economics Literature*, vol. 1, ed. Lee R. Martin, pp. 411–94. Minneapolis: University of Minnesota Press, 1977.

Evans, Carson D. *Balance Sheet of the Farming Sector, 1979*. USDA ESCS Agr. Info. Bull. 430, Aug. 1979.

Grove, Ernest W. "Farm Capital Gains—A Supplement to Farm Income?" *Agr. Econ. Res.* 12(1960):37–42.

Hathaway, Dale E. "Agriculture and the Business Cycle." *Policy for Commercial Agriculture—Its Relation to Economic Growth and Stability*, pp. 51–76. Joint Economic Committee, 85th Cong., 1st sess., 1957.

Hoover, Dale M. "The Measurement and Importance of Real Capital Gains in United States Agriculture, 1940 through 1959." *J. Farm Econ.* 44(1962):929–40.

Melichar, Emanuel. "The Relationship Between Farm Income and Assets Values, 1950–1977." *Food and Agricultural Policy Issues*, ed. Luther Pickrel, pp. 194–200. University of Minnesota Agr. Extens. Serv. Spec. Rep. 71, 1978.

Melichar, Emanuel, and Marian Sayre. "Capital Gains in the U.S. Farming Sector, Nominal and Real, 1940–1974." Presented at the meeting of the Amer. Agr. Econ. Assoc., 11 Aug. 1975. Mimeographed. Washington, D.C.: Board of Governors of the Federal Reserve System.

———. *Agricultural Finance Databook—Annual Series*. Washington, D.C.: Board of Governors of the Federal Reserve System, Nov. 1977.

farm income. However, in 1961, Scofield observed that land prices, which from 1912 to 1940 had moved in an almost parallel fashion with farm income, were diverging from the income trend. He concluded that it was paradoxical for land values to rise without an accompanying rise in income.

In the remainder of this paper, we will attempt to clarify the economics of land valuation and explain what we believe are the underlying forces in the land market. We will also briefly address what is implied for agricultural structure and policy.

We should say at this point that we accept the theory of value which can be stated as

$$V = \Sigma \frac{a_t}{(1 + i_t)^t},$$

where V is the current value of an asset, a is expected value of the annual return in year t, and i is the expected value of the discount rate in year t.

In any year, expected returns are some function of farm commodity and input prices, yields, taxes, interest rates, credit terms, inflation rates, the potential for disposing of the tract for some higher and better use, and a long list of other variables. Discount rates are a function of the time preference for money, risk, and inflation.

Thus, to explain the present value of land we must explain factors which influence expectations of net returns to land and those which explain the formation of expected discount rates. Developing the formula becomes a very complex and somewhat overpowering problem, if all these factors are taken into account. It is tempting to simplify the formula as many appraisers and researchers have done to $V = a/i$ where (a) represents current earnings and (a) and (i) are assumed constant into perpetuity.

Such a formulation frequently has led researchers, lenders, and appraisers to believe that land is overvalued because current returns do not explain current land values. Alternatively, they believe that land earnings are below those in other potential investments. In reality land earnings have not remained constant over time and thus $V = a/i$ has misrepresented actual experience.

Real estate accounts for nearly three-fourths of all farm assets and returns to assets are based on farm income. Thus the relationship between returns to assets and asset values can help in understanding farm real estate

Indexes of Return to Assets and Asset Value

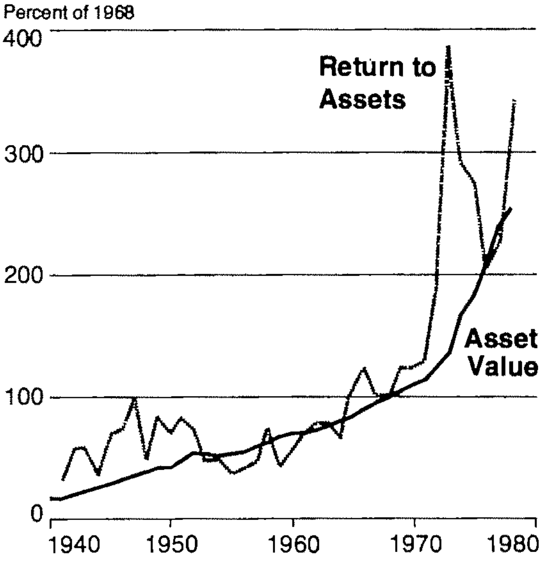


Figure 1. Indexes of returns to assets and asset value 1968 = 100

values (fig. 1). Returns to assets are calculated as a residual by subtracting estimated returns to labor and management from returns to labor, management, and total assets, including borrowed capital and farm assets of landlords. From 1940 through the early 1950s asset returns increased more rapidly than asset values. During the late 1950s and early 1960s values rose slightly more rapidly than asset returns. From 1963 to date the general tendency has been for returns to increase faster than values, even though the increase in returns was interrupted after the 1973 high. Overall since 1940, returns to assets have increased in both absolute and relative terms.

Although data on returns to assets are not available for 1910–40, assets including land are believed to have received a relatively constant share of net income. In that period, land values generally rose and fell with current net income from farming. The share of net returns going to assets rose from less than 30% in the 1940s to more than 60% in the 1970s (fig. 2).

The relationship between cash rents and values also provides evidence that agricultural rents and land values have followed parallel trends in major farm states of the Plains and

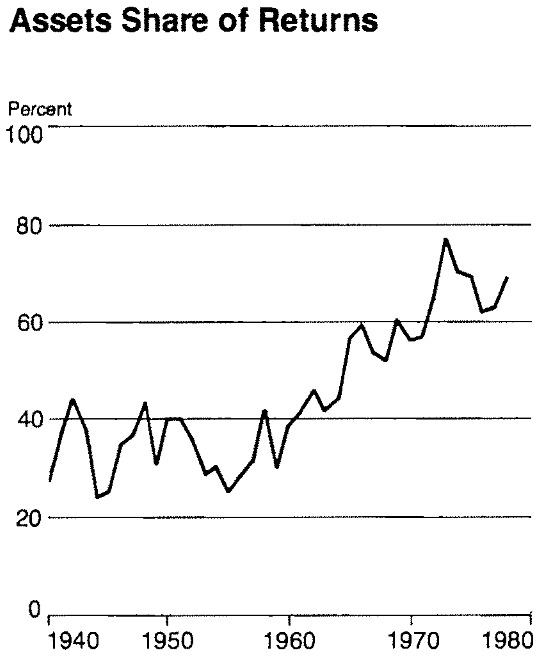


Figure 2. Assets share of returns 1940–78

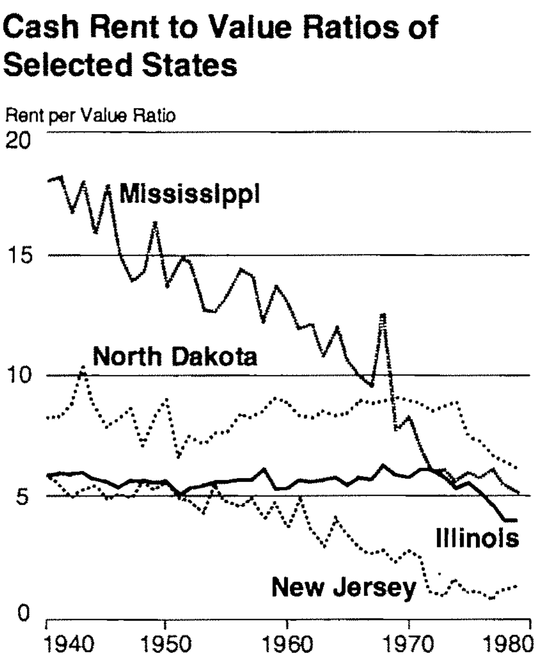


Figure 3. Cash rent to value ratios, 1940–79 selected states

Corn Belt (fig. 3). The ratio of cash rent to value has, therefore, been nearly constant.

In North Dakota and Illinois, for example, the ratio of gross cash rent-to-value remained nearly stable from 1940 to 1970. Trend lines computed for the period show no significant slope. However, since 1970 rent value ratios have declined rather sharply, at a rate of $-.24$ ratio points per year, suggesting that earnings expectations have changed. Apparently, land buyers believed that future returns will exceed current earnings by a substantial margin.

In New Jersey, where agricultural earnings are a minor component of the total expected return from land, agricultural rents have declined in relation to value since 1940. This decline may be explained by the rapid urbanization of New Jersey and by the expectation that future earnings are more likely to come from urban uses than from agricultural production.

Land rents have also declined rapidly in relation to value in Mississippi since 1940. However, the reason for the decline is different from the New Jersey example. In Mississippi, rents in the early years were distorted by imperfections in the land purchase and rental markets. Land was held in very strong hands and many tenants who had few alternatives were competing for the right to rent land. Over time the numbers of tenants declined sharply as nonfarm opportunities increased and production technology changed. Land became more readily available on both the purchase and rental markets. Apparently, a major structural change occurred which brought rent-to-value ratios closer to those of Midwest agriculture.

These data suggest, rather strongly, that an individual buying land at any time during the last forty years would have been in error if he had assumed that earnings would remain constant in the future. Under the conditions which prevailed during this period, it is clear that the ratio of current rents to current values would have represented a substantial understatement of the actual rate of return.

We now ask if it is reasonable to expect land earnings to continue to rise in the future. What factors are likely to determine expectations? If earnings and values are to increase, how will it be possible for new buyers to withstand the substantial cash flow problems that arise in the early years of land ownership with debt financing? We might also question how it

is possible for returns to assets to continue rising in an excess capacity industry.

Assuming that you accept the theory that current land values are determined by expected earnings, we will proceed to explain those factors which have been important in determining expected earnings and, therefore, underlie the demand for land.

Even in a static economy, we would expect land earnings to differ among tracts, areas, and regions, because of soil, climate, population density, mineral resources, and transportation infrastructure. Clearly, such factors impact on earnings expectations and therefore on values. Because much has been written about them, we will say no more about these cross-sectional forces.

The important issue is what causes expectations of earnings and values to vary over time. Perhaps the most important factor, which acts as a demand shifter for land, is population growth. Other things equal, an increase in population will increase the quantity of land demanded at any price. Because the aggregate quantity of land is fixed, earnings will increase as a result of the increased demand for food, fiber, and space. Prices must rise to reallocate land among those who currently own it and those who desire to hold it. Marketing of U.S. agricultural products overseas has an affect similar to a domestic population increase.

Inflation also takes its toll. When prices rise rapidly during a general inflation, production of most goods can be increased at least partly to satisfy the demand, but new land cannot be developed despite strong demand. Thus, land values can be expected to increase more rapidly than the general inflation rate. Buyers also see land as an inflation hedge.

During an inflationary period the tendency is for nominal asset prices to increase as the money supply increases relative to the quantity of the asset. Even if the money supply increases in line with growth in gross national product (GNP), the ratio of money to land is increased and some inflation in land values can be expected. The United States has had a policy of monetary expansion. This policy, we suggest, has been a factor in the increasing land prices.

If the terms of trade in land are modified by changing access to debt financing and interest rates, these changes will shift the demand for real estate to the extent that they modify the ability of buyers with a given set of earnings expectations to bid for land. An extension of the repayment period, a reduction in the downpayment or lower interest rates will each result in an increase in the number of potential buyers at any price. Government guarantees for marginal borrowers, so that lenders are not subject to loss of principal should the borrower fail, have the same effect.

It has often been argued that more lenient credit terms were required to ease the entry of young people into farming. However, such changes in terms benefit only the earliest buyers. Cash flow and equity advantages are soon bid into the price of land. Therefore, with each relaxation in credit terms, land prices can be expected to rise more rapidly, then resume a normal pattern of change with future benefits discounted.

Tax policy also alters the earnings of land through taxation of receipts from production, taxation of appreciation (capital gains), and taxation of real estate values. The government policy of minimizing taxes on capital gains has encouraged investment in real assets, particularly land. Not only have we taxed capital gains at rates well below those on earned income, but we now forgive taxes on the first $100,000 of such gains on residences for those over age fifty-five.

Also, we have increased the size of the inheritance and estate tax exemption and developed procedures to tax estates at "agricultural value" rather than at market value. Such tax laws encourage investment in land and reduce the amount offered for sale.

Preferential or use value assessment of real estate has also changed land values. Depending on how these laws are written they can either increase farm earnings or result in land being held for speculation in nonfarm alternatives, or both.

Among government actions taken to assist farmers are programs designed to increase or at least stabilize farm income. Such programs have directly raised land earnings by increasing the value of the product of land and have indirectly increased earnings by reducing the risk involved in crop production. These programs have operated through direct subsidy to idle land resources and through control of market prices. The net effect of such programs is that earnings and land values which are a function of earnings are higher than they would have been in their absence.

The implications of continuously rising land values for the structure of the agricultural sector are that current land owners will benefit

from wealth changes at the expense of future generations of farmers. If nominal earnings and values rise faster than the general price level, it will become increasingly difficult for prospective farmers to acquire viable farm units. Land ownership and wealth will tend to become concentrated into fewer hands as current land owners add marginal units to existing operations. Entry into farming will occur mainly through inheritance. Few tenants will obtain sufficient capital to become owners. Control of land resources will go to those with the greatest wealth and highest earnings expectations. This process is likely to be aided by policies arising from our concern for the beginning farmer. We can expect continued increases in land values. Our production sector is likely to differ greatly from the Jeffersonian ideal.

Concluding Remarks

If the land market is not allocating land resources and wealth in a manner consistent with economic or social objectives we must consider impacts of present actions and recognize potential consequences of alternative policies.

It would be possible to tax capital appreciation at the same or a higher rate than earned income, reduce the incentive to hold land as a store of value, and slow the accumulation of wealth. Use valuation for real property and estate taxes could be restricted. We could limit borrowing against real estate. This would decrease leverage that current land owners obtain from appreciation in real estate values. We could modify the tax law so that interest payments on real estate were no longer deductible. Commodity income programs could be eliminated or greatly modified to increase market risk and reduce land earnings. All land sales could be controlled by a government agency with redistribution to "worthy" farmers. Acreage limitations could be applied to land holdings. It would be possible to restrict corporate control of farm land to leasing arrangements of thirty years or less, thus placing them on planning horizons similar to individuals.

Such actions would tend to limit concentration of ownership, reduce competition in the land market, increase the risk of farming, and probably limit gains in production efficiency. But which of these policies would be economically, socially, and politically acceptable as means to limit further land price increases and further concentration of wealth? Although we may not like it, if we are serious in our concern over rising land values, we will need to consider such actions.

References

Bergland, Bob. Remarks before the National Farmers Union Convention, Kansas City, Mo., 12 Mar. 1979.

Gray, L. C. Paper presented to the American Farm Economics Association, Nov. 1919.

Scofield, William H. "The Land Price Paradox." Contributed paper presented at Amer. Agr. Econ. Assoc. meeting, Ft. Collins, Colo., Aug. 1961.

Wiecking, E. H. *Farm Real Estate Situation*. USDA Bureau of Agr. Econ., Feb. 1926.

Implications of Divergence in Sources of Returns in Agriculture

James S. Plaxico

Over the short run, resource prices affect the level and mix of inputs and outputs and determine the distributive share to the factors of production. Over the longer run, resource prices impact on the structure of control in all sectors of the economy. In this paper attention is focused on structural implications of rapid changes in U.S. farmland prices. Land price increases are hypothesized to stimulate consolidation of land control (ownership) with an attendant shift in income and wealth positions within agriculture and perhaps between agriculture and other sectors. Alternative future scenarios are sketched as a means of considering implications and available policy alternatives are suggested.

Ownership Expansion Potential

The changing distribution of farm size is a result of the differential rates of growth among farms. Individual ownership expansion is limited by equity and cash flow considerations. Current income contributes to equity and/or cash flow. Asset price increases provide a base for expanded credit finance, but do not satisfy cash flow requirements.

The potential land ownership expansion rate, based on land appreciation equity, depends on the rate of land price increase and equity requirement. Land price increases can only increase the cash equity requirement for land acquisition for the nonowner. Land purchase potential, based on earnings, depends on the level of earnings, the income tax bracket, the rate of change of land prices, the proportion of earnings available for investment, and the cash equity required. The marginal tax rate affects the potential rate of expansion very little but the cash equity requirement has a major impact.

James S. Plaxico is a professor of agricultural economics at Oklahoma State University.

Oklahoma Agricultural Experiment Station Journal Article No. 3665.

Risk-oriented, established, owner-operators and landlords have the potential to expand land holdings rapidly given rapid land price increases and modest earnings. A 10% rate of land price increase provides the equity base for a 27% per year expansion in ownership to meet an overall 25% equity requirement. This in turn would require a first year annual cash flow of approximately 3.5% of the land value assuming all acres owned are leveraged so that the overall equity ratio is 25%.

Several conclusions appear inescapable. Land price increases create the potential for large owner-operated farms to become much larger and raise barriers to entry into farming of those who have no land ownership base. Given rapid increases in land prices, cash flow requirements constitute the major barrier to ownership expansion. Cash flow declines threaten the financial survival of operators who have expanded at rapid rates. Yet, a moderately favorable cash flow situation with continued land price increases results in very large wealth increases among large farmers.

Ownership patterns and structure need not be directly related, yet in the United States the trend is evident. Breimyer states it succinctly: "More than most farm leaders will acknowledge, fully as much as many farmers sense without being able to articulate, and definitely beyond what most agricultural economists are willing to recognize, the era of cheap land, of land subordinate to operatorship in farming, is fading from the American experience" (1978, p. 10).

The Structure of Farmland Prices

A recent analysis suggests that farm income and expected capital gains were major forces in U.S. farmland prices over the 1940–77 period (Kuhlman). Farm income and expected capital gains were estimated in a second degree polynomial lag structure. The capital gains variable exhibited regression coefficients higher for each of the lagged variables than

was the case for farm income. These results suggest that expected capital gains had a greater impact on land prices than an equal expected income increase. Is farmland in the United States becoming a vehicle for storing and preserving wealth? The question is an important empirical one, for policy alternatives available are dependent on the answer.

Gains occur in nonrevenue generating assets (e.g., gold, art, jewels) presumably because these assets offer a useful vehicle for value storage and preservation. Yet economists often argue that farmland capital gains (FCG) occur solely because incomes are expected to increase. Unfortunately, economists frequently ignore the current value of unrealized capital gains because they think of returns as annual income flows and view managers as maximizing a utility function closely related to annual income flows. Yet capital gains constitute an important source of returns, impact on the aggregate consumption function, and affect investment and production decisions. Wealth accumulation may be superior to income as a simple proxy of the utility surface.

In the national income accounts, capital gains and losses are excluded since the objective is to measure the net annual flow of goods and services, but capital gains and losses have been shown to affect individual consumption (and saving) behavior. Thus capital gains and losses cannot be ignored in evaluating the economic welfare (income) of individuals and groups nor in asset pricing.

Grove argued that it would be inappropriate to add net income from farming (NIF) and FCG to derive an overall income measure because "they are not entirely comparable magnitudes." NIF is largely a realized gain while FCG are mostly nonrealized. Also FCG are likely distributed in a different pattern than is NIF. Bhatia hypothesized that capital gains could enter the consumption function via either an income or a wealth effect. In the Bhatia income approach equations, the coefficients relating to both realized and accrued gains were positive. In the wealth approach equations, the coefficients for both accrued and realized gains were positive and significant but the coefficients associated with expected gains were smaller than those associated with expected income. Bhatia's results suggest that farmers have a high propensity to save from FCG. This is logical since FCG amount to forced saving. Plaxico and Kletke found that accrued FCG values to individuals appear to be similar for both the income and wealth approaches.

If farmland owners place a value on wealth accumulation, FCG could have a value as large as an equal disposable NIF in determining land values. Where cash flow is not a pressing problem, this could be essentially correct. This situation may describe a majority of recent farmland buyers. Bhatia (p. 877) concluded, "in all likelihood, people treat realized gains like any other income." Baquet (p. 76) treats gains as equivalent to income.

The most viable hypothesis at this point is that FCG have a value at least equal to an equal additional disposable income for current farmland purchasers in determining farmland values. Yet the simple sum of FCG and NIF is an inadequate basis for gauging the economic well-being of the farming population because of the different patterns of distribution.

Two Scenarios

Two scenarios are constructed to identify implications of changing sources of return in agriculture. NIF is assumed to remain essentially unchanged (as has been the case in real terms since 1940) while land prices are assumed to increase in the first case while remaining stable or declining in the second case. The scenarios appear consistent with observed relationships, but implications for the future are extrapolations. In both scenarios, hobby and subsistence farm units are likely to increase in number but not in terms of market share.

I-*The Rising Farmland Price*

Farmland ownership (control) will be consolidated rapidly due to growth of already large farms with a corresponding decline in the number of medium size (family) farms. The large units will grow as a consequence of financial expertise and leverage with marketing advantages playing a lesser role. Growth will not be due to scale economies in production. Initially large farms will be predominantly owned by individuals and these owners will be the economic elite in the economy—whether they reside in Boston, Zurich, or Gotebo. Large established units will become attractive acquisition targets for large corporations and for pension fund investments as es-

tates are settled. Corporate-owned farmland will generate modest dividends, but stockholder enchantment will not wane as net worth and stock values rise.

Capital, management, and labor functions will be separated. Initially tenants will farm the land—until a unionized labor force in agriculture emerges. The factor share to land will increase with a concurrent decline in the labor factor share, a continuation of the current trend (Cleveland and Ray). Labor cost rates in agriculture will equal nonfarm wages. Agriculture as a way of life will pass and agriculture will have lost its uniqueness in the American scene (Paarlberg).

Public support of agricultural research and education will decline. Research will be funded by private agribusiness interests and the results will be proprietary and findings will be guarded—not extended. Land grant institutions will lose their unique advantage as teaching institutions as they decline in importance as agricultural research centers—but those with the leadership, foresight, and desire will adjust to new funding patterns and emerge as the "prestige institutions" of the twenty-first century. The agricultural economics profession may be replaced by systems scientists, applied economists, business managers, accountants, and attorneys.

II-*The Stable Farmland Price*

Static land prices will stimulate selling by the highly leveraged, rapidly expanding units where farm debt growth appears to be most rapid (Melichar), and among the smaller low equity operators. Buyers will be conservative, high equity, larger family farms, and a few nonfarm investors.

Average size (however measured) units will continue to increase relative to the present, but less than in scenario I. Ownership will be concentrated among larger scale family farmers. Commodity market structures will be under some pressure but change will come slowly (Rhodes). Public research and education in agriculture will be viable, but formula funding will decline and confusion with respect to direction of research and education programs will be increasingly evident.

Class action suits concerning the apparent distribution of the benefits of publicly supported research will become common. Numerous land grant university agricultural colleges will flounder, fade, and fold, but two groups will survive. One will receive substantial public funding, as grants or contracts, in support of basic and/or public interest research and education. The other will engage in proprietary work in the interest of private agricultural clients. Farm income will be more skewed than is now the case, but less than in scenario I. The factor share to land will increase and that to labor decrease relative to the present but less than under the previous scenario. Agricultural economics as a profession will survive in some public institutions but growth is less likely than decline.

Does It Matter?

Production scale economies are achievable by moderate-sized family farmers, yet per unit costs do not increase as size increases. There are differences among enterprises, most associated with financing and marketing considerations, but structure appears to have little impact on resource productivity, supply or perhaps food production costs. However, changes in the farming structure alter the distribution of income and wealth within agriculture and between agriculture and other sectors of the economy.

Conservation levels and environmental quality appear not to be affected by structure. Small farms may use less fossil energy per unit of output than larger units, but there is no evidence that very large farms use energy more or less efficiently than family-sized units. Both appear to be highly energy dependent, but energy efficient, within the context of current price ratios.

Concentration in agricultural production may impact on food prices. Yet concentration in broiler production appears not to have retarded productivity advances nor resulted in prices above competitive levels, but market behavior associated with a given structure may be different in different industries. Also structure may limit access to markets and disrupt current pricing arrangements, and structural change is likely to be irreversible.

Farming jobs have been eliminated or transferred to the nonfarm sector as a result of a changing farming structure. A further structural shift may further reduce onfarm employment and farming opportunities. Some believe that a farming environment produces superior citizens. A structure of small farms better supports local businesses and institu-

tions than does a very large farming structure. What are the social and individual costs of a changing farming structure which reduces access to farming opportunities, alters income and wealth distribution patterns, changes the backgrounds of future populations, and accelerates the demise of small business communities and local institutions with an attendant shift in economic, social and political control?

Policy Options

Rapid land price increases are a major force leading to a concentrated agricultural production structure. Forces which tend to give wealth increases a greater utility than current income, make farmland prices rise relative to comparable assets, and make it less expensive for heirs of landowners than others to enter farming, are important contributing factors. The impact of commodity programs on long run structural change may not be established (Gardner, p. 842) but Gaffney argues, "The proximate beneficiary of most farm programs is the land owner per se. . . . The collateral of high land values lures more capital into agriculture. . . . A system of instant pleasure and deferred pain lends itself nicely to the demand of the American political process. . . . Land plays the role of Lorelei. The siren song . . . is the lure of the unearned increment" (pp. 1252–63).

If one accepts that the forces identified lead to a more concentrated production structure, and society desires to modify change, the policy objectives are clear. They are: (*a*) modify the rise in land prices, (*b*) reduce the appeal of wealth increases relative to current income, (*c*) make intergeneration transfer of wealth more difficult, and (*d*) design commodity support programs so that benefits accrue to factors other than land. These objectives are not interdependent and in some cases conflict, thus the details of policy options to achieve a desired structure are much less clear. Policies relating to the four objectives identified are outlined. Three of the four objectives relate to overall economic and tax policy. It is increasingly clear that farmers no longer control the agenda germane to agricultural policy.

Modify Land Price Increases

If general inflation leads to the use of land as a store of value, measures to stem inflation will contribute to controlling land price increases. Higher property taxes on land reduce the investment appeal of land. A property tax rebate for owner-operators and a size progressive tax rate are two available specialized instruments. Specific measures could be directed to land price modification but these would require direct controls which many would consider to be unduly onerous. Limiting use of certain land to agricultural production is an example. Restricting sales of agricultural land to operating farmers to discourage speculative holdings is another possibility. An ultimate measure would be the creation of a public trust authority to hold title to agricultural land. The land would then be leased to farm operators on a long-term basis. The trust authority could be financed by investors with rates of return controlled in a manner similar to public utilities and others granted monopoly positions in the economy.

A family farming structure requires new entrants and existing family units must continue to invest to maintain efficiency. Easier agricultural credit increases the demand for farmland, but it is not clear that restrictive credit would contribute to the maintenance of a family farming structure. The question is an empirical one—and an unanswered one.

Make Wealth Increases Relatively Less Attractive

Preferred tax treatment of capital gains is viewed as a means of stimulating investment to enhance productivity and economic growth rates. Price increases in existing assets do not increase national wealth—nor is productivity directly affected. The public interest might best be served by tax institutions that stimulate net new investments in productivity and growth rather than rewarding holding of assets for price gains. The investment tax credit may be one such vehicle and accelerated depreciation allowances also appear to contribute, although application of these to existing assets likely results in a degree of slippage.

Intergenerational Wealth Transfers

Cash accounting systems permit accumulation of wealth which has not been subjected to either current income nor capital gains tax. Current use valuations facilitate the entry of members of farm families into farming, while entry of individuals from nonowner farm fami-

lies is made more difficult. Yet corporate assets are not subject to estate type taxation. Thus it is not obvious that less liberal estate taxation would contribute to the maintenance of a family-farming structure.

Benefits of Farm Programs

Few innovative ideas for altering the distribution of farm program benefits have been advanced. If individuals view land as the limiting factor, the distribution of farm program benefits among the productive factors is unlikely to be affected significantly by farm program changes.

Perspective

Rapid consolidation of agricultural production units is not a phenomenon of the 1970s (Stanton). During the professional lifetime of many members of this association farm numbers have declined by more than 50%. What is new is the sustained rapid rise in farmland prices which provides a base for rapid further consolidations. Over several decades of farm consolidation, the rhetoric of farm leaders and farm legislation has been in support of the maintenance of the family farm (Breimyer 1977). However, the family farm has been defined and redefined with sufficient flexibility that leaders seem to agree that our current structure is a family farm dominated one, albeit a very different one than that of past decades. Will we continue to redefine the family farm to be the mode of current structure, or have we now attained a structure to be preserved for all seasons and all decades?

The paradox that farm leaders tend to seek programs that ameliorate current problems but escalate long-term structural change rates is well known and understandable. Again, near term pleasure and deferred pain are consistent with the short terms of elected officials. Nevertheless, there is a surprising paucity of hard data to permit a real indepth examination of structural change in farm production and to evaluate implications of alternative policies. The structure issue is a political one. There are available ample policy instruments to modify structural change but there is no evidence of a political constituency to cause the rate of change to be slowed.

Our profession is indebted to the small core group that has recognized and identified the structure concern. The challenge before us is to quantify and monitor the changing nature of the dilemma as well as to measure potential policy impacts. The high profile, which recent comments of the secretary have given the structure issue, certainly gives impetus to the work ahead.

References

Baquet, Alan E. *A Theory of Investment and Disinvestment Including Optimal Lines, Maintenance and Usage Rates for Durables.* Ph.D. thesis, Michigan State University, 1978.

Bhatia, K. B. "Capital Gains and the Aggregate Consumption Function." *Amer. Econ. Rev.* 62 (1972): 866–79.

Breimyer, Harold. *Farm Policy: 13 Essays.* Ames: Iowa State University Press, 1977.

———. "Farm Policy 1978: Recycled Old or Innovative New?" Mimeographed. College of Agriculture, Oklahoma State University, 7 Mar. 1978.

Cleveland, O. A., and Daryll E. Ray. "Optimum Resource Allocation for Selected U.S. Agricultural Commodities." *S. J. Agr. Econ.* 5(1973):223–31.

Gaffney, Mason. "The Benefits of Farm Programs: Incidence, Shifting, and Dissipation." *J. Farm Econ.* 47 (1965):1252–63.

Gardner, Bruce L. "Public Policy and the Control of Agricultural Production." *Amer. J. Agr. Econ.* 60 (1978):836–43.

Grove, Ernest W. "Farm Capital Gains—A Supplement to Farm Income?" *Agr. Econ. Res.* 12 (1960):37–42.

Kuhlman, Richard H. "An Econometric Study of Factors Affecting Farm Land Prices, 1940–1977." M.S. thesis, Oklahoma State University, 1978.

Melichar, Emanuel. "Some Current Aspects of Agricultural Finance and Banking in the United States." *Amer. J. Agr. Econ.* 59(1977):967–76.

Paarlberg, Don. "Farm Price and Income Support Programs and the Future of the Family Farm." *Can the Family Farm Survive?*, ed. Harold Breimyer, pp. 54–56. University of Missouri, Agr. Exp. Sta. Spec. Rep. 219, 1978.

Plaxico, James S., and Darrel D. Kletke. "The Value of Unrealized Farm Land Capital Gains." *Amer. J. Agr. Econ.* 61(1979):327–30.

Rhodes, V. James. "Small Farmers and Big Markets." *Can the Family Farm Survive?*, ed. Harold Breimyer, pp. 48–53. University of Missouri Agr. Exp. Sta. Spec. Rep. 219, 1978.

Stanton, B. F. "Perspective on Farm Size." *Amer. J. Agr. Econ.* 60(1978):727–37.

Land Prices, Inflation, and Farm Income: Discussion

R. J. McConnen

Melichar's exciting paper points out that the increases in agricultural land prices we have experienced can be explained by examining macrodata in a microframework. In the process of this analysis, Melichar shows, "real capital gains on physical assets were on the average nearly as large as the current returns from 1954 through 1967 as well as in the 1970's." This means that at no time since the mid-1960s has per capita "farm income" been less than per capita nonfarm income—when "farm income" includes current return plus real capital gains on physical assets. In these terms, our agricultural income problem of the past twenty years has been primarily a problem of income distribution caused not only be differences in farm size, education, access to capital, etc., but also by difference with regard to farm ownerhsip. If Melichar's asset pricing model is modified so that g is defined as "the expected annual growth rate of the current returns expressed in terms of certainty equivalence," table 2, section A becomes conceptually useful as a means of interpreting the impact of policy changes which can range from price and income policy to crop insurance programs to multinational trade negotiations. Any widespread change in either the expected annual growth rate of current returns or the level of risk in agriculture would cause dramatic changes in perceived equilibrium land values. For example, if we use an 8% discount rate in table 2 and if the forces of protectionism in world trade were perceived to be gaining ground and the expected annual growth rate fell from 6% to 4%, land values would fall by one-half.

The Reinsels use Gray's 1919 statement to verbalize Melichar's asset-pricing model. Their data on cash rent to value ratios underscore their statement that, "an individual buying land at any time during the last forty years would have been in error if he had assumed that earnings would remain constant in the future." Their concluding section begins, "If the land market is not allocating land resources and wealth in a manner consistent with economic and social objectives, we must consider impacts of present actions and . . . alternative policies." The desirability of policy instruments which would change farmland prices can only be judged in the context of the impact on more broadly based and accepted economic and social objectives.

Plaxico has presented a clear exposition of the role of increasing land prices on the structure of agriculture. Plaxico asks, "Does It Matter?" It does matter, but structure should not be regarded as an end in itself but rather as a means of achieving economic and social objectives we have not as yet been able to agree upon.

Can we predict all of the consequences of the alternatives suggested by the authors this morning? I think not. Politically, how feasible are some of the suggestions? After all, it was Howard Jarvis not Henry George who was the inspiration for Proposition 13. We are at the stage where we must give careful study to the consequences of alternative solutions. When we see the results of these studies, we may elect to accept an unpleasant phenomenon rather than to promote some unacceptable cures.

Thomas Schelling begins *Micromotives and Macrobehavior* by describing the seating patterns at a lecture he once gave. He speculates systematically on the reasons for this seating pattern and states, "The most interesting question is not how many people would like to change their seats after they see where everybody else is sitting; it is whether some altogether different seating arrangement might better serve the purposes of many, or most, or all of them. How well each does for himself in adapting to his social environment is not the same thing as how satisfactory a social environment they collectively create for themselves" (p. 19). Schelling points out that we

R. J. McConnen is a professor in the Department of Agricultural Economics and Economics, Montana State University.

should not evaluate the resulting social environment merely by examining the acceptability of the micromotives. However, we must understand micromotives if we are to design effective policy instruments which we can use to generate acceptable macrobehavior. The micromotives which give rise to the perceived macroproblems with regard to land prices and farm income extend beyond agriculture and rural America. For example, as Plaxico points out, farmland has been a good hedge against inflation. It is unlikely that any policy to hold down farmland price increases would be successful unless there are also changes in generally held expectations about future inflation rates.

An *Economist* article on Britain's Northfield Committee Report on Agricultural Land states that the "phoney problems" of voracious buying of farmland by financial institutions and by foreigners were disposed by the report as unfounded. "The real problem is a quite different one: the voracious buying of farm land by the private, British yeoman farmer. —entrepreneurial farming has become much harder to get started in than other small businesses—and it cannot be desirable that this should become a strictly hereditary occupation. The answer is the landlord; and the committee makes no bones about being thoroughly in favor of him—Rather than special pleading for more special cases, the Northfield committee would have done better to ask what methods of farm finance (yes, and what levels of farm income) would enable the industry to bear its share of this tax burden and yet thrive" (pp. 70–71).

I refer to the Northfield Report for two reasons. First, the United States is not the only nation facing the problems that are the subject of this session. Second, some of the suggestions of the Northfield Report and the comments in the *Economist* are not among those that would be generally popular in the United States. I think both points suggest we badly need to do some comparative studies. I do not think we have much evidence that an agricultural structure based on large farms will be either less efficient or more unstable than the agriculture we have today. I think the real issues of the evolving agricultural structure in the United States are two; one, as Plaxico points out, deals with the distribution of income and wealth and the second deals with our old friend, agricultural fundamentalism. As economists, we can recognize the second issue and provide—I hope—useful information about the first. If we are to inform rather than misinform, we need to do some careful work. I expect that some of our results will not be popular.

The issues raised in these papers will remain important issues. I believe we can expect current returns to continue to grow over the long run. And that will mean continuing increases in land prices. I think the principal reason will be a significant future growth in export markets of the European Economic Community and China for U.S. agricultural products. I think many American farmers would agree with me. We may be wrong, but by the time that is demonstrated, the structural damage will be done. Unless of course we decide, on the basis of income and wealth distribution considerations, to implement policies which will modify the likely outcome.

References

The Economist. "The landed view of land." 14 Jul. 1979.

Schnelling, Thomas C. *Micromotives and Macrobehavior*. New York: W. W. Norton & Co., 1978.

Land Prices, Inflation, and Farm Income: Discussion

Duane G. Harris

Although the papers presented by Melichar, Reinsel and Reinsel, and Plaxico address different aspects of the land-value, land-income issue, they all attempt to identify factors affecting value and offer policy prescriptions for solving perceived problems associated with the so-called income-price paradox. The purposes of this comment are to critique the conceptual formulations used by the authors and to evaluate the logic of a few conclusions and policy implications drawn by the authors from their respective conceptual models.

Land Valuation Models

As Melichar has noted, the valuation of land can be regarded as analagous to the valuation of a "growth stock" in which part of the return comes to the owner in the form of current income and part in the form of capital appreciation over time. The standard growth stock valuation model (VanHorne, p. 22), therefore, is useful in examining the land-income, land-value relationship. The general form of the growth model is given by

$$(1)\quad V_o = \frac{R_o\,(1+g)}{(1+k)} + \frac{R_o\,(1+g)^2}{(1+k)^2} + \ldots + \frac{R_o\,(1+g)^n}{(1+k)^n},$$

where V_o represents current value, R_o is current income, g is the expected rate of growth over time of current income, k is the capitalization rate and n is the number of years of income generated by the asset. Because the growth model assumes a particular pattern of income over time, it is less general than the valuation model presented by Reinsel and Reinsel. However, the Reinsel formulation, because it is the most general form, offers little insight into the relationship between income and value. The growth model presented in equation (1) also is more conceptually appealing than the Melichar model in which value itself is assumed to grow at a rate g over time.

If we consider land to be an asset with infinite life ($n \rightarrow \infty$) and assume that in the long run the capitalization rate is greater than the expected rate of growth of income ($k > g$), equation (1) can be reduced to the following form:

$$(2)\quad V_o = \frac{R_o\,(1+g)}{(k-g)}.$$

Note that equation (2) is the same final result as that obtained by Melichar with his more restrictive initial assumptions about growth in value. While the Reinsel model allows us only to conclude that land values will depend on factors affecting annual income and the capitalization rate, the growth model emphasizes that value will be dependent as well on factors affecting the growth in income over time.

Additional insights into the valuation process can be obtained by examining the components of the capitalization rate. The capitalization rate can be expressed as a function of the required rates of return on debt and equity

$$(3)\quad k = w_d k_d + w_e k_e,$$

where k_d and k_e represent the required nominal rates of return on debt and equity, respectively, and w_d and w_e are the proportions of the asset portfolio respectively financed by debt and equity. Furthermore, if the individual rates of return are broken down into real rates and inflation premiums, equation (3) can be reformulated as

$$(4)\quad k = w_d(r_d + \theta_d) + w_e\,(r_e + \theta_e),$$

where r_d and r_e represent real rates of return

Duane G. Harris is an associate professor in the Department of Economics at Iowa State University.

Journal Paper No. J-9648 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, Project No. 2117.

and θ_d and θ_e represent inflation premiums on debt and equity holdings, respectively. Finally, if debt and equity holders all have the same inflationary expectations ($\theta_e = \theta_d = \theta$), then equation (4) simplifies to

$$k = w_d r_d + w_e r_e + \theta, \tag{5}$$

and equation (2) can be rewritten as

$$V_o = \frac{R_o\,(1 + g)}{w_d r_d + w_e r_e + \theta - g}. \tag{6}$$

We now see that land values are formulated to be a function of current income (R_o), expected growth in income (g), real required rates of return on debt and equity (r_d and r_e), the financial mix used to purchase and hold assets (w_d and w_e), and inflationary expectations (θ). As such, the model given in equation (6) is more explicit in its identification of factors affecting land values than either the Melichar or Reinsel formulations.

Models, Evidence, and Policy Implications

The evidence presented by Melichar on the time trend of land values and income, when properly measured, is consistent with the growth model formulation and suggests that ad hoc explanations for the "apparent" historical divergence between income and value may be misdirected. Melichar's data indicate that long-term growth in the real value of land has been accompanied by long-term growth in real income received from land. If we can hypothesize that a pattern of historical growth in real income generates expectations for continued growth in real income, then the growth model can be judged to be a useful characterization of the land valuation process in the marketplace. As such, the model can serve as a starting point for the definition of problems associated with rising land values and for the identification and evaluation of policies that may have an impact on land values and the structure of U.S. agriculture.

For example, the Reinsel and Reinsel postulate that population growth is a factor that will cause land values to continue rising in years to come is conceptually consistent with the growth model. Their contention, however, that general inflation will cause land values to rise is not so easily substantiated by the model. It is not clear that general inflation will necessarily lead to an increase in the income received from land. Also, if general inflation generates inflationary expectations, equation (6) suggests that an increase in inflation premiums demanded by debt and equity holders (θ) would, *ceteris paribus*, cause land values to decline.

In addition, Reinsel and Reinsel and Plaxico identify government tax policy as a factor affecting the value of land. However, the impact may be neither as direct nor as obvious as the authors would suggest. It is important to appropriately introduce taxation into the land valuation modeling process (Adams) in order to draw quantitative implications of changes in tax policy.

Finally, it is likely that any governmental policy designed to enhance or stabilize farm income will be inconsistent with an objective of stabilizing land prices. Especially aggravating to land value stability are policies linking support prices to costs of production (Harris, Boehlje and Griffin). Thus, as Melichar points out, we should seek out those policies that do not tend to increase the long-term growth in return to farming.

References

Adams, Roy D. "The Effect of Income Tax Progressivity on Valuation of Income Streams by Individuals." *Amer. J. Agr. Econ.* 59(1977):538–42.

Boehlje, Michael, and Steven Griffin. "Financial Impacts of Government Support Price Programs." *Amer. J. Agr. Econ.* 61(1979):285–96.

Harris, Duane G. "Inflation-Indexed Price Supports and Land Values." *Amer. J. Agr. Econ.* 59(1977):489–95.

VanHorne, James C. *Financial Management and Policy*, 4th ed. Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Returns to Public Irrigation Development and the Concomitant Costs of Commodity Programs

William E. Martin

Development of agriculture and associated agricultural problems have had a prominent place in congressional deliberations virtually throughout the history of the United States (Benedict). Early policy stressed land development, and the Reclamation Act of 1902 was in such spirit. It was "An Act Appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands." With later modifications of policy to provide greater sources of income for works construction, Congress continues to support the Bureau of Reclamation's water development output-increasing activities.

Yet, since 1929, with time out for war, the federal government also has effected commodity programs designed to reduce the supply of major agricultural commodities so as to maintain product prices "at levels that would be above the market price in a free and reasonably normal market situation" (Benedict, p. 517). Such a situation would tend to strike most economists as peculiar (inefficient). Howe and Easter estimated the annual costs of commodity programs directly related to reclamation irrigation in the range of $83 million to $179 million during the period 1944 to 1964 (p. 143). Some of the "facts" generated by these apparently contradictory policies are the subject of this paper.

In the past two decades resource economists, including myself, have severely criticized Bureau of Reclamation project evaluation procedures. Young summarized these criticisms and concluded that if we explicitly adopt a national accounting stance such that benefits and costs are evaluated from the point of view of the whole nation ("to whomsoever they may accrue . . ."), and if we assign a dominant role to economic efficiency in our assessment, "there would have been only a very few, if any, projects initiated in the past two decades which would have met the B-C criterion" (p. 260).

I will not dwell on all the criticisms, but there is one issue that is of particular importance to returns to irrigation development and associated costs of commodity programs. Water development projects traditionally are evaluated outside of a general equilibrium context, and it is assumed that each single project will have no effect on commodity prices. While the elasticity of demand for agricultural output may be close to infinite for the Bureau's smallest, 221-acre project, it could not be infinite over all of its 9.3 million irrigated acres. It is because of the existence of downward sloping demand curves that there could be a rational economic reason for simultaneous irrigation development and agricultural income support programs if questions of welfare and distribution are considered. Thus, in this paper, I first develop a simple conceptual framework of the costs and benefits of public irrigation development, then examine some of the relevant empirical data, and finally draw some rough conclusions as to our country's relative economic rationality.

A Conceptual Framework

Traditional B-C analysis has looked only at the producer side of the issue. As in figure 1A, demand has been assumed to be infinitely elastic while irrigation development shifts supply from S_1 to S_2. There is no consumers' surplus before development and none created by de-

---

William E. Martin is professor of agricultural economics at the University of Arizona, Tucson.

Arizona Agricultural Experiment Station Journal Article No. 3030.

The author benefited from conversations with Russell L. Gum and Dennis C. Cory.

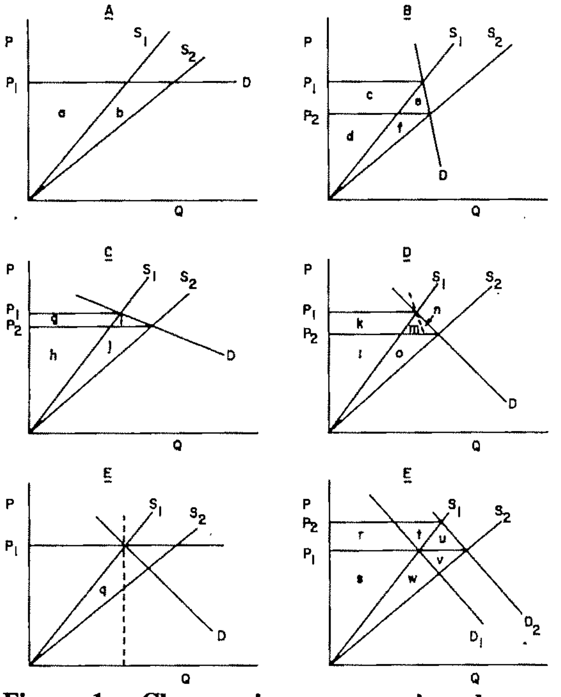


Figure 1. Changes in consumers' and producers surpluses resulting from irrigation development (hypothetical)

velopment. Producers' surplus is assumed to increase from area a to area $a + b$ through development. Area b would be available for producers to repay project costs. Consumers would have no interest in the whole process if they were not usually required to provide a subsidy.

In fact, the situation is as shown in figure 1B. Given a downward sloping demand, project development will create additional consumers' surplus equal to $c + e$. Producers lose c to the consumers, but gain f. The water is there on the farm, $f - c$ may or may not be positive, but the water will be used, output will increase and $c + e$ is always positive.

A distributional problem is created. As with b in figure 1A, f in figure 1B accrues to the recipients of the new water and is available to repay project costs. The loss, c, comes from all producers, old and new. Even if all loss comes from producers outside of the project development area, f is smaller than b and repayment ability will be smaller than computed under the assumption of constant prices.

As is evident from figures 1B and 1C, the relative gains to consumers and gains or losses to producers depends on the elasticity of demand. With an inelastic demand, gains to consumers ($c + e$, figure 1B) are large and losses to all producers are probable. With an elastic demand, consumers gain less ($g + i$, figure 1C) and all producers have a chance of a net gain ($j - g$). Producers in the project area have a chance at project repayment, since j (figure 1C) is not too much smaller in size than b (figure 1A).

A caveat is required on the measurement of consumer gains. If we assume that consumers have a right to their original position (p_1, figure 1D) rather than their subsequent position (p_2), and that the income elasticity of demand is not zero, the more accurate concept of gain is that of compensating variation (Hicks; Currie, Murphy, and Schmitz) rather than simple Marshallian consumers' surplus. For a price fall, compensating variation is the maximum consumers' willingness to pay to achieve the subsequent equilibrium condition. Because of income effects, this amount is less than simple Marshallian consumers' surplus. Compensating variation is shown as $k + m$ in figure 1D, less than consumers' surplus by n. Willig argues that for small changes in consumers' surplus for goods with an income elasticity in the range of $\pm$ 1.0, n is negligible.

We thus have a case for a consumer subsidy to producers where an irrigation project lowers the prices of agricultural products. While we may be sacrificing national economic efficiency, the consumer should be willing to pay up to a maximum of $k + m$ (figure 1D) to gain the distributional effects of increased quantities at lower prices. This amount will be larger where the project produces products for which there is an inelastic rather than an elastic demand. The subsidy could be in the form of zero interest on irrigation project repayment charges—past and current practice under reclamation law or through direct support payments on the commodities. ("Current projects are subsidized to over 80 percent of costs, if the interest on a normal repayment period is factored in" [Young, p. 262]). However, it is important that output be allowed to increase and prices allowed to fall. If the original price is maintained through production controls (figure 1E) there is no consumer gain to provide a subsidy. While there is a total gain in producers' surplus of q, since all producers must be limited if the project is to produce, project farmers will gain at other producers' expense. In this case it is hard to argue that either efficiency or distributional equity would be served.

We may go further in the argument for a

consumer to producer subsidy if we allow demand to shift to the right as would be expected with population growth. Assume an original position at the intersection of S_1 and D_1 (figure 1F). With demand projected to rise to D_2, consumers should be willing to pay up to $r + t$ to avoid the price rise. (See Burns for surplus estimation with shifts in demand.) If prices actually rise to p_2 with the shift in demand, consumers could pay $r + t + u$ to regain their former position of p_1. Of course, the anticipated or actual shift in demand, with the accompanying growth in producers' surplus of $r + t$, should create pressure for irrigation expansion by producers under a market solution. However, project costs could exceed $w + v - r - t$ or there simply could be market failure (Young, p. 3).

Public Investment in Irrigation Development

Bureau of Reclamation facilities do not comprise the entire investment in U.S. irrigation. In fact, Bureau of Reclamation facilities serve only 9.3 million acres while "other project facilities" serve 13.3 million (U.S. Department of Agriculture 1979). ("Other" projects include BIA and Corps of Engineers projects as well as state and private development.) Private on-farm facilities serve another 22.7 million acres for a net farm irrigated acreage of 45.3 million out of 367 million acres in "planted crops and fallow" in the United States (pp. 28, 39). But the net value of the capital investment in Bureau projects in 1975 was \$8.960 billion out of \$9.005 billion net federal investment, with other group projects valued at only \$2.370 billion. Private individual facilities were valued at \$4.640 billion (p. 27). Thus, in terms of federal investment, Bureau projects comprise 99.5% of value. In the context of the issue of federal commodity programs versus federal irrigation development, I will concentrate on the acreage in and output from Bureau projects.

U.S. and Bureau of Reclamation Acreages

In table 1 U.S. acreage and Bureau of Reclamation acreage are compared by crop. Of the cereals, barley and rice are the only crops with Bureau acreage exceeding 1%, with 6.1% of U.S. barley and rice acreage each. Total cereal acreage on Bureau lands is less than 1.1% of the U.S. total. Bureau lands are 6.6% of U.S. alfalfa acreage, but probably less than 1% or 2% of total forage acreage. Thus, we find that while forages and cereals are grown on 62% of all Bureau lands (37% and 25%, respectively) (U.S. Department of Interior 1978b), they are but a percentage point or two of U.S. forage and cereal lands.

Field crops are a different matter. Twenty-four percent of the dry bean acreage is on Bureau lands, 30% of sugar beet acreage, 10% of cotton acreage, and 72% of all hop and mint acreage. But with soybean acreage negligible, total miscellaneous field crop acres on Bureau lands are less than 2.4% of the U.S. total.

The speciality crops—vegetables, fruits, seeds, and nuts—are the major crops on Bureau lands when compared to U.S. acreage. Vegetables are on only 9% of Bureau lands but account for close to 18% of U.S. acres. Fruits and nuts are on 8% of Bureau lands but account for 21% and 32% of U.S. fruit and nut acreage, respectively. Seeds are but 2% of Bureau lands but approximately 11% of U.S. seed acreage.

To summarize, lands currently irrigated by Bureau of Reclamation projects are only 2.5% of total U.S. cropland, but they contain a significant percentage of vegetable, fruit, nut, seed, and miscellaneous field crop acreage, as well as a significant acreage of barley, rice, and alfalfa.

The Incremental Output from Federal Investment

More important than mere area is the productivity of the irrigated lands. In table 2 is shown the 1977 production of major crops grown on Bureau lands, the index for yields from wholly irrigated lands as compared to unirrigated lands, and the implied increment in production due to irrigation on Bureau lands as a percentage of 1977 total U.S. production. Also shown is total Bureau production as a percentage of total U.S. production.

Two assumptions are crucial to the estimates of the increment from irrigation. First, it is assumed that cotton, dry beans, vegetables and melons, and orchards would not be grown in the absence of Bureau irrigation. Thus, for these crops total production is equal to incremental production. Second, for all crops it is assumed that no other irrigation water was available; that is, that the Bureau was required

Table 1. Total U.S. and Bureau of Reclamation Cropped Acreage, by Major Crops, 1977

Crop	U.S.[a]	Bureau of Reclamation[b]	Bureau of Reclamation as a Percentage of U.S.
	------------ 1000 acres	------------	
Cereals			
Barley	10,586	647	6.1
Corn	82,680	646	0.8
Oats	17,793	86	0.5
Rice	2,261	139	6.1
Rye	2,652	1	0.0
Sorghum	16,994	96	0.6
Wheat	74,804	595	0.8
Other	?	116	—
Total	>207,770	2,327	<1.1
Forage			
Alfalfa	27,085	1,791	6.6
Other hay	33,408	242	0.7
Irrigated pasture	?	987	—
Other forage	?	432	—
Total	>60,493	3,452	<3.4
Miscellaneous Field Crops			
Dry beans	1,395	335	24.0
Cotton	13,694	1,476	10.0
Hops and mint	116	83	71.5
Sugarbeets	1,277	379	29.7
Soybeans	59,080	8	0.0
Other	?	33	—
Total	>75,562	1,784	<2.4
Vegetables			
Potatoes	1,349	257	19.1
Melons	322	67	20.8
Other vegetables	>2,786	470	<16.9
Total	>4,457	794	<17.8
Fruit			
Citrus	1,163	154	13.2
Major deciduous	1,657	427	25.8
Minor fruits	108	42	38.9
Berries	45	2	4.4
Total	2,973	625	21.0
Nuts	471	152	32.3
Seeds	>1,587	175	<11.0
Total cropland[c]	367,000	9,310	2.5

[a] USDA, Agricultural Statistics, 1978, various tables.
[b] USDI, 1977 Land and Water Resource Accomplishments, 1978a, table 4.
[c] ESCS staff, Natural Resource Capital in U.S. Agriculture, tables 6 and 17. These estimates are for 1975. Individual crop estimates do not add to total because of different sources and missing acreage estimates.

to develop full water service rather than merely supplemental water service. Both assumptions obviously cause an overestimate of the increment from irrigation, since 54% of all lands irrigated by the Bureau receive supplemental rather than full water service (USDI 1978b).

Given these caveats, we see that the greatest increases in production caused by Bureau water are for vegetables, melons, orchards, and dry beans. Other significant increases are for cotton, rice, barley, alfalfa, and potatoes. The increments in corn, oats, sorghum, wheat, and soybeans are each 1% or less.

Now let us examine recent participation in the major commodity programs. In table 3 are shown the quantities of commodities pledged to the commodity credit corporation under the commodity loan programs, as percentages of total U.S. production for the years 1972 to 1977. (Flaxseed, honey, naval stores, peanuts, rye, and tobacco—not produced on Bureau lands—are excluded. These commodities, along with storage facility and equipment loans comprised 16% of the 1977 loan pro-

Table 2. Increments in Production from Irrigating Bureau of Reclamation Lands, 1977

Commodity	1977 Bu. Rec. Production[a] (1,000s)	Index for 17 Western States[b]	Implied Dryland Production (1,000s)	Increment from Irrigation as Percentage of 1977 U.S. Production	Total Bu. Rec. Production as Percentage of 1977 U.S. Production
Barley	49,914 bu.	205	24,348 bu.	6.1	12.0
Corn	59,346 bu.	181	32,788 bu.	0.4	0.9
Cotton	1,663 bales	256	[c]	11.6	11.6
Dry beans	6,374 cwt.	309	[c]	39.1	39.1
Oats	5,908 bu.	153	3,861 bu.	0.3	0.8
Sorghum	6,259 bu.	193	3,243 bu.	0.4	0.8
Soybeans	263 bu.	126	209 bu.	negligible	negligible
Wheat	44,776 bu.	187	23,944 bu.	1.0	2.2
Rice	7,978 cwt.	[d]	0	8.0	8.0
Alfalfa	—	230	—	5.8[e]	10.2
Potatoes	—	179	—	9.9[e]	22.5
Vegetables and melons	—	318	[c]	26.9[e]	26.9
Orchards	—	214	[c]	25.6[e]	25.6

[a] USDI 1978a.
[b] USDC, *1974 Census of Agriculture*. Compares irrigated with nonirrigated.
[c] Dryland acreage in the West is minimal.
[d] No dryland acreage.
[e] Based on index and relative acreage.

gram.) If we take these quantities as a rough measure of farmer and congressional perception of excess agricultural production, we might compare them with production increments associated with public irrigation investment. These increments, developed in table 2, are also presented as the last column of table 3.

A portion of all of the cereal grains consistently has gone under loan during this recent six-year period. In 1977, 10.8% of the barley crop was pledged while the public irrigation increment was 6.3%. Only 0.5% of corn production was pledged—but the irrigation increment was 80% of that amount. Oats and sorghum were each pledged at about 6% of production even though the irrigation increment was minor. Less rice was pledged in 1977 than the Bureau increment, but large quantities had been pledged in previous years. Wheat was heavily under loan (20%) even with only a 1% public irrigation increment.

The two commodities with the largest production increment from public irrigation investment, dry beans and cotton, while pledged in earlier years, apparently were clearing the

Table 3. Quantity of Commodity Pledged to the Commodity Credit Corporation and Increment in Production from Irrigation on Bureau of Reclamation Lands as Percentages of Total U.S. Production

Commodity	Year 72	73	74	75	76	77	Increment from Irrigation 1977[a]
	%						
Barley	10.1	3.7	2.3	2.5	4.9	10.8	6.1
Corn	7.5	4.6	1.6	2.5	4.4	0.5	0.4
Cotton	14.2	13.6	21.4	8.4	9.0	0.3	11.6
Dry beans	5.3	0.4	0.5	0	0	0	39.1
Oats	4.6	1.6	0.6	0.6	0.8	6.5	0.3
Sorghum	3.7	2.0	0.6	1.2	2.9	5.9	0.4
Soybeans	7.1	8.0	2.9	0	1.7	0	negligible
Wheat	9.2	3.5	2.0	2.3	22.1	20.1	1.0
Rice	26.8	20.6	8.2	16.7	20.2	4.6	8.0

Source: USDA *Agricultural Statistics 1978*.
[a] See table 2.

market at "satisfactory" prices in 1977. No beans were pledged in 1977 although the irrigation increment was 39.1%. Only 0.3% of cotton was pledged while 11.6% of U.S. production was attributable to public irrigation investment.

Costs and Benefits

How might these data be interpreted? Clearly the grains have generally been and continue to be in "excess" supply relative to congressional intent. But irrigation development seems not to be a major culprit, except perhaps with barley. The problem would exist even without public irrigation development. On the other hand, irrigation investment to grow these crops is obviously unnecessary. The problems with cotton, dry beans, and soybeans seem to be lessening. At least with dry beans, one might see a need for having developed production. Still, overall one could hardly argue the necessity of public water development from the point of view of the U.S. producers of these commodities. That the commodity programs exist is enough evidence that water has not increased net income. Benefits, if there are any, must be on the consumers' side. A consumer should be willing to pay to have larger quantities with lower prices. Unfortunately, the mechanism for subsidies generally has not allowed the consumer to receive full benefits.

Consumer benefits surely have been achieved with investment in water for fruits, nuts, vegetables and melons, potatoes, and perhaps even alfalfa. While many of these crops, with the exception of alfalfa, have been under marketing orders, with the obvious intention to restrict output and raise prices, the very magnitude of their position in total U.S. production suggests a positive benefit. The problem is, of course, that even though demands for most fruits and vegetables are more elastic than for the basic commodities, they still are inelastic. Therefore, a downward shift in supply tends not to benefit consumers greatly—perhaps not enough for project and producer subsidy.

Let us work backwards to see what consumer benefits would have to be if the federal water projects were to be beneficial. The 1975 Bureau of Reclamation gross real investment in irrigation project facilities was $9.1 billion (USDA 1979). This value "represents the estimated cost of reproducing all existing irrigation . . . works at unit costs prevailing in [1975]" (p. 43). If consumers were to receive the full value of the irrigation investment, an annual total return of $910 million would be required if the investment were evaluated at an interest rate of 10%. With a 1975 estimate of "number of people eating from civilian food supplies" of 211 million (USDA 1978a, p. 552), the required annual per capita consumer's surplus would need be only $4.31. Given the large amounts of vegetables, fruits, and nuts that are incremental in Bureau of Reclamation Project acreages, I do not find a $4.31 consumer benefit unbelievable.

In fact, annual per capita subsidy costs of Bureau project construction have been at most about $3.50 in 1975 dollars. I make this estimate as follows. Given the 1975 estimate of $9.1 billion for reproducing all existing irrigation facilities, and assuming amortization at 10% for 50 years (the normal payback period), total principal and interest would equal $45.891 billion. North and Neely estimate that current projects are subsidized to about 80% of costs, when the interest in the normal repayment period is included. Eighty percent of the total is $36.713 billion, or $734 million per year (of which only 20% is principal). With a 1975 population of 211 million, the annual per capital subsidy would be $3.47. Of course projects have been constructed over the past seventy-five years. In any given year only a portion of the 153 projects actually would be under repayment.

However, because of commodity programs for cereals and field crops, there is the additional cost of government payments to farmers. Since World War II, total payments have varied from 0.6% (1974) to 7.9% of total farmers' cash receipts from marketings on a national basis (USDA 1978b). In 1969 a per capita consumer contribution of $19.06 is implied, in 1974 the contribution was only $2.52, and in 1977 the contribution rose again to $8.47. The problem here for consumers is that they are paying for the privilege of not having higher quantities and lower prices on cereals and field crops. Thus, the costs must also be absorbed by any benefits to vegetables, fruits, and nuts.

What might be the total incremental benefits to these crops? Per capita food expenditure in 1977 was $1,136 (USDA 1978c). Ten percent of this expenditure was on fruits and vegetables (USDL). Given a price elasticity of demand for fruits and vegetables of around

−0.75 (George and King, p. 49), and assuming an increment in U.S. production of fruits and vegetables of 26% (table 2), the incremental consumer's surplus attributable to public irrigation would be $34.26 per capita. Perhaps Bureau projects really have been worth the associated commodity program costs.

The data presented have summarized the past and presented the current status of public irrigation investment and commodity programs. What of the future? I cannot help believing that because the less expensive project sites have already been developed, future development will be slight. People slowly are beginning to realize that water naturally runs downhill and to reverse that phenomenon requires energy. For example, Arizona's Salt River Project, the first construction activity of the Bureau, is a major producer of electrical energy. Currently, the Central Arizona Project is under construction. It will require a quarter of the output from the three 750-megawatt coal-fired units of the Navajo Generating Station to lift the water more than 2,000 feet uphill (University of Arizona).

Let us examine the recent trends in construction activities and the crops grown on these new irrigated acres, as a possible clue to the future. The twenty years for which Young suggests negative benefit-cost ratios should serve. Since 1960, in the last 27% of the Bureau's history, 35% of its 153 projects have come on-line, but these projects irrigate only 10.6% of its land. Since 1970, 15% of Bureau projects began producing on only 3.4% of Bureau land. Apparently we are not running out of projects, only land on which to put them. Further, while between 1960 and 1968 acreage developed with full water service was 1.3 times that developed with supplemental service, since 1970, 4.4 times as much supplemental service has been developed than full service (USDI 1978a). Supplemental service may well reduce fluctuations in crop yields, but surely develops a smaller production increment than full service development. I suspect many of the supplemental-water projects are so called "rescue" projects, such as the Central Arizona Project, where the marginal cost of not having the "rescue" water is very small (Kelso, Martin, and Mack).

Finally, we may ask what crops are being grown on these newer project acreages. Economists, including myself, have generally argued that projects should be evaluated in terms of the MVP's of the lowest valued crops—the grains and forages, and that higher valued crops—fruits and vegetables—would be grown in any case if a market were available. From an efficiency point of view the correctness of this argument seems clear. However, the data show that since 1960, the total Bureau land increase of 10.6% was associated with a 10.9% increase in project vegetables, a 23.4% increase in project nuts, an 8.7% increase in project fruit and 9, 11.5, and 10.6% increase in project cereals, forages, and miscellaneous field crops, respectively. In other words, all crops tended to increase proportionately to land in projects. In the years since 1970, the 3.4% increase in Bureau lands include a 21.7% increase in project nuts, a 5% increase in project fruits, a 4.6% increase in project vegetables, almost proportional increase in project forages and field crops, but only a 1.4% increase in cereals.

These data, however, could be misleading. An increase in project fruits or vegetables need not mean a net increase in fruit or vegetable acreage of the same size—especially on supplemental-water projects. As shown above, recent projects are mostly supplemental. Still, one might suspect a positive distributional effect toward consumers.

Conclusions

While it is clear that recent public irrigation development projects are economically inefficient from a national accounting stance, logical economic arguments can be made, at least for past projects, on the basis of distributional gains to consumers. Such gains are probable even in the face of the costs of our national commodity programs. The gains could be substantial if output were not restricted and if any farmer income support were handled through direct income payments.

Arguments for future development are much weaker. Low-cost project sites no longer exist. Projects now use energy rather than develop it. Alternative uses for water in high MVP uses are growing. The increments from the development of supplemental water are not as large as from the full service projects that made the deserts bloom rather than merely "rescuing" marginal acreages. If the intent of Congress remains to provide inexpensive food to consumers while supporting producer incomes, new directions in both

water development policy and farmer support policy are clearly necessary.

References

Benedict, Murray R. *Farm Policies of the United States.* New York: The Twentieth Century Fund, 1953.

Burns, Michael E. "A Note on the Concept and Measure of Consumer's Surplus." *Amer. Econ. Rev.* 63 (1973):335–44.

Currie, John Martin, John A. Murphy, and Andrew Schmitz. "The Concept of Economic Surplus and Its Use in Economic Analysis." *Econ. J.* 81 (1971):741–99.

George, P. S., and G. H. King. *Consumer Demand for Food Commodities in the United States.* Giannini Foundation Monograph No. 26, University of California, Berkeley, March 1971.

Hicks, J. R. "The Four Consumer's Surpluses." *Rev. Econ. Stud.* 11 (1943):31–41.

Howe, Charles W., and K. William Easter. *Interbasin Transfers of Water: Economic Issues and Impacts.* Baltimore, Md.: Johns Hopkins University Press, 1971.

Kelso, Maurice M., William E. Martin, and Lawrence E. Mack. *Water Supplies and Economic Growth: An Arizona Case Study.* Tucson: University of Arizona Press, 1973.

North, Ronald M., and Walter P. Neely. "A Model for Achieving Consistency for Cost Sharing in Water Resource Programs." *Water Resour. Bull.,* 13 (1977):995–1005.

University of Arizona. *Arizona Energy: A Framework for Decision.* Res. Rep. for the 28th Arizona Town Hall, March 1976.

U.S. Department of Agriculture. *Agricultural Statistics 1978,* 1978a.

———. *Fact Book of U.S. Agriculture.* Misc. Pub. No. 1063, Nov. 1978b.

———. *Natural Resource Capital in U.S. Agriculture.* ESCS Staff Paper, Mar. 1979.

———. *Working Data for Demand Analysis.* ESCS Revis. Mar. 1978c.

U.S. Department of Commerce, Bureau of the Census. *1974 Census of Agriculture, Irrigation and Drainage in Farms,* vol. II, part 9. Washington, D.C., June 1978.

U.S. Department of the Interior, Bureau of Reclamation. *1977 Water and Land Resource Accomplishments, Statistical Appendix 1,* Washington, D.C., Nov. 1978a.

———. *1977 Water and Land Resource Accomplishments, Summary Report.* Washington, D.C., Nov. 1978b.

U.S. Department of Labor, Bureau of Labor Statistics. *Consumer Expenditure Survey: Integrated Diary and Interview Survey Data, 1972–73.* Bull. 1992, Washington, D.C., 1978.

Willig, Robert D. "Consumer's Surplus Without Apology." *Amer. Econ. Rev.* 66 (1976):589–97.

Young, Robert A. "Economic Analysis and Federal Irrigation Policy: A Reappraisal." *West. J. Agr. Econ.* 3 (1978):257–67.

On Augmenting Community Economic Performance by New or Continuing Irrigation Developments

Herbert H. Stoevener and Roger G. Kraynick

Having been asked to present a paper at this meeting on the above topic reflects the continuing existence of an unresolved issue among agricultural economists: the nature and extent of regional development impacts of irrigation developments. We do not want to foster the expectation that our paper will resolve this problem. Instead, we shall attempt to sort out some of the major policy issues involved, classify relevant empirical studies on this subject, and make some suggestions for research approaches in this area.

The concern for this issue is old and relates mainly to two subjects which are interdependent yet in some respects are analytically separate from one another. First, there is the question whether or not irrigation developments convey to the subregion in which they take place regional development benefits which matter from a national benefit-cost accounting stance. In traditional benefit-cost analysis these are referred to as "secondary benefits." Second, there are circumstances under which it is important to compare benefits and costs from the standpoint of the region in which irrigation developments are to take place. We shall turn to a discussion of these two viewpoints.

The Concept of National Secondary Benefits (Once Again)

Considerable effort has gone into studying the kinds of secondary benefits which are allowable in the evaluation of public investment. This effort did not begin in earnest until after World War II. However, there continued at that time a significant degree of satisfaction with the phraseology, "to whomsoever they may accrue" in regard to the categorization (and thereby distribution) of net benefits.

The *Proposed Practices* in both the original (May 1950) and the revision (May 1958) consider the deficiency in the above dictum (U.S. Inter-Agency River Basin Committee). The 1958 version states specifically that "secondary benefits . . . usually have little significance in project formulation, economic justification and array." That these local secondary effects in the region in question would be offset by effects with the opposite sign in other regions had become well established.[1] There are only two conditions under which secondary benefits could arise. The first deals with the issue of surpluses (in, say, fixed as well as variable capital stock) in with- and without-public investment situations. The surpluses which could be incorporated into additions to the local capital stock are relevant because (the official reason) some regions may have a comparative advantage over others when implementing such additions and because (the reason proposed below) the process by which such surpluses are implemented may be influenced significantly by the nature of the primary investment itself. The second condition under which the nationally relevant secondary benefits could arise involves the capacity utilization of the existing resources. The extent to which unemployed and underemployed labor resources in a potential area can be employed has emerged as a bona fide benefit category for federal programs. As men-

Herbert H. Stoevener and Roger G. Kraynick are professor and research associate, respectively, in the Department of Agricultural and Resource Economics, Oregon State University.

This is Oregon Agricultural Experiment Station Technical Paper No. 5253.

[1] The official procedure now in effect for reporting local secondary benefits is spelled out in the November 1973 Principles and Standards and remains unchanged in the May 1979 version. Agencies still have the discretion to display secondary benefits in project authorization requests: The Bureau of Reclamation has claimed 18% of gross irrigation benefits, Soil Conservation 10% of total net benefits, while the Corps of Engineers does not display calculated secondary benefits. As noted below, the Area Redevelopment Benefits claimed for proposed projects are currently permitted. (See U.S. General Accounting Office.)

tioned below, capacity utilization of other existing resources has not received as much attention.

The surplus issue has not received the attention that the unemployed resources issue has, but would seem nonetheless to be a key element of whether these kinds of national secondary benefits are to be of any real relevance. Kneese and Margolis, among others, have each mentioned the process by which the surplus-related secondary benefits may emerge. In the former, it was termed a "dynamic" secondary effect, with inference to the kinds of jump steps or lumpiness in the fixed and/or variable capital stock of a local community. Margolis, on the other hand, combined the surplus issue into one involving the fact that a project in sparsely populated regions will result in more efficient use of existing social overhead capital. Whether or not one finds these significantly different from the general class of external economies depends on whether the process by which surpluses accrue to the community in a public investment situation is important.

The evidence on process of making a surplus addition to the fixed and variable capital stock of a local region is not encouraging. First of all, for those economists willing to discuss it at all as something outside the realm of gravity models (and other locational techniques), the term "agglomeration" has tended to be more of a handicap than a help, a point which has been recently expanded by Papageorgiou.

Some economists have expressed belief that conventional economic models may be limited in dealing with socioeconomic processes within rural communities. In particular, it is thought that much of the performance of small towns with respect to issues such as rapid growth are shaped by the nature of key groups of individuals. Tweeten and Brinkman cite the literature in this area much of which refers to "legitimizers" who are "the people in almost every community that seem to have the right, authority and prerogative to sanction activities" (p. 262). Furthermore, as Powers observed, these top influential leaders have the following characteristics: they are usually over fifty years of age with above average education, are in higher income groups having access to or control of money, credit, jobs, mass media, and are longtime residents of the community who are self-employed, owners, or executives.

Most applied regional economists and community development specialists have some personal experience with a power structure in a locality or region. It is frequently observed that in addition to confirmation of the above premises many of the influential community leaders are involved in a multiple of development activities. Powers also notes that many of the influential leaders hold a significant proportion of their assets in real estate. There is some evidence that in a land-intensive investment project economic returns increase to the affected land itself and spill over to other land. Under these circumstances we hypothesize that a process of "venture capital formation" may take place in the local private sector. The resultant availability of local capital may release some previously existing constraint on regional economic development.

These observations parallel some made by Barkley in discussing the variations in water/community relationships. We would suggest that many of the variations that he discusses are due to whether or not surpluses that accrue locally are used locally. Barkley also makes a point about the mining project(s)-community relationships which occurred in many places in the West in the nineteenth century. Those towns that were abandoned are, of course, examples of surpluses which were unwisely invested in local fixed capital.

Testing the hypothesis that the process of local venture capital formation is a significant element of irrigation-related regional growth poses some problems in data gathering and analysis. The reporting of local (perhaps sub-county) financial indicators is limited: annual reports of private bank and other financial institutions can provide some comparisons between areas. The frequency and magnitude of building permit applications and observations on the value of residential and commercial construction and property exchanges may reveal information on the source and extent of finance which can be generated in relevant localities. In any case, necessary data are limited requiring careful consideration of models to be tested.

The unemployment-underemployment issue in the determination of national secondary benefits has been treated in a definitive manner by Haveman and Krutilla. Empirical estimates of the true opportunity cost of labor were made by relating the major occupational categories employed in public project construction

so as to generate the unemployment rates in these particular categories. Based on 1960 conditions, it was concluded that the opportunity cost of project construction from 1957 to 1965 was between 65% and 85% of the nominal expenditures on construction. Although Haveman and Krutilla build their analysis of unemployed labor resources on a national and major regional basis, it is reasonable to draw similar conclusions for small regions or even communities where water development is taking place. It is less convincing, however, to argue that local idle capacity in industry, commerce, and the service sectors will become fully employed because of public investment activities in a small region. Often new capacity-reflecting changes in technology and consumer preferences become installed, a process of "leapfrogging" over the existing idle capacity. Although economies of scale may be realized in these new investments with respect to all new development, the unit costs tend to be made higher than comparable ownership costs in the vintage capacity. It is difficult to gauge whether these growth effects per se are relevant in the sense of Haveman and Krutilla. As indicated above, the process by which they take place as a result of a public investment stimulus is important to understand.

The most recent decade has seen at the national level to some extent a revival of interest in the analysis of regional economic benefits under the framework of multiple objective planning. This is perhaps mainly because of the Water Resources Council's planning guidelines which view regional development as an objective to be considered side by side with national economic development, environmental quality, and social well-being. Major (1969, 1977, and Major and Lenton) has been the principal intellectual proponent of the approach, arguing that national and regional net benefits can be viewed like competitive products (with a range of complementarity) in a production possibilities framework. According to Major the slope of a social indifference function can be inferred from past legislative action. This yields the choice criterion and appropriate weights on the objectives, allowing the set of projects yielding the optimal combination of national and regional net benefits to be chosen. A similar argument is also developed by Schramm.

Major's suggestions have been criticized, perhaps most pointedly by Freeman and Haveman. They challenge the categorization of regional development benefits, as they are likely to overlap with national benefits, making their representation in a production possibilities framework impossible. They also have less faith than Major in the possibilities of deriving weights for multiple objectives from legislative records. Instead, they insist on an explicit specification by the decision maker of the relative "deservingness" of the various regions. Only in this manner could coefficients be derived by which net regional benefits could be weighted.

Local Social Overhead Capital

Before turning to our second topic, let us comment briefly on the subject of regional costs. The costs of expanding public services in rural communities to accommodate growth stimulated by irrigation development have been found to be significant by several authors (e.g., Whittlesey and Butcher 1978). These, of course, should be weighed against the gross regional benefits of irrigation projects. In doing so, one should be cognizant of any potential scale economies in local government, the possibilities for incorporating cost saving technologies in service delivery, and the value of public service outputs generated by the additional expenditures.

Although most of the evidence on scale economies in public services has emerged with respect to urban services, Hamilton and Reid have suggested that such economies are possible in rural areas because the evidence suggests that marginal costs are below average costs. Evidence for specific areas of government services has recently been summarized by Fox et al. Scale economies in public service provision are found not to be mythical, but one should be careful about generalizing these results to the case of rural community growth. In such cases, for example, large one-time incremental costs of service expansion can occur. Relevant monetary measures for values of many types of public sector outputs are still unavailable.

We would like to conclude this section by stating that the short answer to the existence of regional benefits from water planning is negative. There are, however, complex conceptual issues involved which do not rule out the existence of such effects in certain circumstances. Their measurement is generally difficult.

The Local Viewpoint on Regional Benefits

Whether or not regional benefits relevant to a national water-planning standpoint can or should be estimated is only one question of our paper. Our other interest lies in the contribution which irrigation development may make toward the development of the region, as such a contribution is perceived by the region itself. The logic for the existence of such benefits is much clearer than for the case of nationally relevant secondary benefits. Their empirical estimation is, however, a different matter. We believe that there is some confusion in the literature on this point. We shall turn next to these empirical questions, focusing on each of three measurement approaches.

Young discusses federal irrigation development and regional economic growth in a recent paper. While he is explicit about adopting a national accounting stance he refers to the "mythology" of a strong linkage between irrigation water development and regional economic growth to explain pressures by western political leaders for further developments of this kind. Note that the enthusiasm of regional representatives for capturing regional benefits does not depend upon the existence of such benefits from the national accounting stance. They merely need to exist from the viewpoint of the region in question. Nor does Young argue against regional benefits on logical grounds. He refers instead to empirical studies to challenge their existence. We shall turn briefly to two of these, the ones which appear most closely directed at western irrigation development.

The first of these is a study by Cicchetti, Smith, and Carson. It is succinctly summarized by Young:

> Two analyses were performed: A Cobb-Douglas production model and a linear growth equation model. Deflated subregional income and deflated value of farm output were the proxy measures of output. In the production model, variables representing Bureau investment in irrigation facilities were not found to have any significant impact on regional income and only a small and not convincingly significant impact (t-value = 1.62) on value of farm output. The growth equations showed sub-regional incomes to be positively related to some USBR investments as well as to state and local government expenditures on education, health, and so on. However, irrigation investment did not enter as a significant variable in any of the growth equations. Coefficients for those Bureau investments which were significant, hydropower, flood control, and recreation, were often unstable between periods of analysis and in the case of hydropower, with negative sign. (p. 264)

We should add that in the production function model, subregional farm output is explained by three variables: farm employment, and capital stock measures for Bureau of Reclamention investments in irrigation, and hydropower. Average subregional income is viewed as a function of nonfarm employment and capital stock variables for Bureau investments in hydropower and flood control. Cicchetti, Smith, and Carson caution us in the interpretation of their equations as they "have not fully specified all inputs to the production process" (p. 3), a statement with which we must agree wholeheartedly.

The "growth equations" approach is slightly more complex. Even here what starts out as a reasonably specified conceptual model results in an attempt to explain changes in the value of farm output, for example (over the two ten-year periods between 1950–60 and 1960–70), by Bureau investments in hydropower, state and local expenditures on highways, and the change in farm employment. Various equations are estimated, with 1950–60 data "pooled" with those for the 1960–70 decade and for the two time periods separately. There are large apparent differences in many of the regression coefficients depending on how the data sets are aggregated. In one instance, four out of five regression coefficients have the opposite sign in the equation based on 1950–60 data from the ones based on 1960–70 data.

Another study cited by Young is the one by Fullerton et al. We concur with Young's judgment that this study was done with care and rigor and that it does not offer support for the hypothesis that regional economic growth is caused by investment in water resources. But it is easy to overdraw the conclusions from this study. We should heed the authors' cautioning. With respect to their large area statistical analysis they say: "Although we have argued that the statistical findings do not support the hypothesis that regional growth is induced by water investment, we have been somewhat reluctant to offer them in support of the alternative hypothesis, i.e., water resource investments do not result in economic growth impacts. In other words, it is conceivable that such investment does have regional growth effects but that our data and analysis have

failed to pick it up because of a variety of problems" (p. 43).

Fullerton et al. then go on to describe various data and analytical problems which beset cross-sectional studies of this type. They mention the problem of various data being observed at different time periods, water resource investment data not being available with sufficient specificity about timing and geographic incidence of possible impacts, and, finally, the possibility that the impacts of public investment projects may simply be swamped by other developments which affect a much larger proportion of the agricultural land base.

We do not want to appear excessively critical of the multi-area statistical approach to measure regional economic development impacts from irrigation investments. In the recent past we have been encouraged that some independent research in the classroom has focused on this very problem. But the conclusion appears almost inescapable that this approach allows little to be said definitively about the phenomenon in question.

Normal constraints on research resources force reliance upon secondary data, and the problems described by Fullerton et al. are likely to occur. To the latter we would add that especially for large federally sponsored irrigation projects there is the additional problem that the other purposes of such projects, especially flood protection, hydropower production and recreation may have their own regional impacts which may be distributed differently from those of irrigation with respect to space and time. Finally, the focus of the studies cited has been on public investments in irrigation development. In several ways one would expect private developments of this type to have the same impacts as those under public sponsorship. One type of development may even be a substitute for the other. Failure to take account of private irrigation development and other public and private means to intensify agricultural production in areas where such developments are important is likely to make statistical analyses of this type unproductive.

Observations on Land Valuations to Estimate Returns to Irrigated Land and Adjacent Communities

In the late 1950s, Renshaw suggested the use of land values as indirect or proxy measures of the *ex ante* benefits of irrigation projects. The analysis of land values had been popular in the preceeding decade, but rarely with the purpose of determining irrigation-related benefits. A study by Selby in 1945 is a notable exception.

The hypothesis tested by Renshaw is, of course, built on the premise that farm land value represents a capitalization of expected net income derived from production on the land. The term "value" obviously can be interpreted in many ways; Renshaw's definition in one model involved capitalization of repayment streams received by the Bureau of Reclamation from irrigation districts. Another model used average data on land values for states, a third used census data, and a fourth involved questionnaire data. Renshaw's models all involved regressing these land value measures against crop value or some indices of crop value. As such, Renshaw was unable to pursue any questions of the value of water applied to the land.

Milliman's review of Renshaw's work revealed that there are possibilities of obtaining more information on the benefits of irrigation than in conventional budget approaches. In particular he notes that the number of variables to consider is reduced, land values already entail an implicit discount rate reflecting local points of view on risk and uncertainty, and the possibility of double counting of benefits is reduced.

The use of crop values as the sole independent variable as in Renshaw omits some important determinants of irrigated land prices. The basic premise is, of course, that any increase in land values resulting solely from the provision of additional irrigation water represents a market capitalization of the

$$\begin{pmatrix}\text{present discounted value}\\ (PDV)\text{ of expected future}\\ \text{stream of value received}\\ \text{from water}\end{pmatrix}$$
$$\text{minus}$$
$$\begin{pmatrix}PDV\text{ of stream of}\\ \text{actual water service}\\ \text{costs}\end{pmatrix}.$$

In formulating a model based on this premise, according to Milliman, one should take several qualifications into account. With respect to costs, agricultural land is treated as the only fixed factor in production. Furthermore, water is assumed to be the primary causation of production which requires treating all other vari-

ables as a part of the land factor or not at all. Another cost issue which is particularly relevant to federal irrigation development is whether the cost stream being evaluated understates the "true" cost stream involved. If so, one would expect a surplus to be capitalized in the land value. With respect to the stream of benefits, it is necessary to account for any potential loss of security in the agreement to purchase water or in the inherent rights to the use of water. Similarly, taking account of potential transfers to other uses, particularly for residential development, will complicate the land valuation model.

Milliman extends this latter point to a discussion of external economies, particularly the enhancement of land values on commercial and residential property surrounding irrigation development. It also has been demonstrated that external economies of the pecuniary type can be significant in the evaluation of irrigation development such as in the pending completion of the Columbia Basin Project and the proposed irrigation of Desert Land Act and Carey Act lands in southwestern Idaho as demonstrated by Whittlesey and Butcher and U.S. Department of the Interior, Bureau of Land Management, respectively. In both cases the externality is encompassed in product prices and in certain factor costs stemming mainly from the increasing cost of electricity.

How accurate are land value techniques for assessing net primary benefits attributable to irrigation development? Beale's multivariate model of land values on four existing Bureau of Reclamation projects reveals considerable apparent disagreements between this method and the conventional *ex ante* budget determination of net primary benefits. Whereas *ex ante* benefit-cost (B-C) ratios calculated by the budget method (primary benefits) ranged from 0.82 to 1.9, the land value method yielded a range from 0.27 to 0.78. The differences were explained in a minor way by the difference between *ex ante* and *ex post* operation and maintenance (O and M) charges. The principal difference, however, arises because of the rates used in discounting the stream of benefits: a given rate (2.5%) in the budget method and a set of implicit rates (ranging from 7.9% to 11.4%) in the land value method. If these latter rates are representative of the opportunity cost of capital in the region applied to somewhat risky ventures, then the two methods may be assumed to be yielding similar evaluations. The Bureau rate, of course, significantly underestimates not only the opportunity cost of money, but also the risk premium implicit in private lending rates.

Beale's observations on land values were taken from the 1960s when fairly stable relationships existed between land values, net returns to irrigated agriculture, and the general rate of inflation. Since 1972, however, land prices have accelerated sharply, net farm income has been very volatile, and nonland production costs (now being led by higher energy costs) have increased faster than the general price level (Lee and Rask). Decisions to invest in farm land have become significantly more complex with buyers having to consider not only net returns to land and the opportunity cost of money but also the specific terms of both purchase and taxation and a crucially important estimate of selling price at the end of a suitably long planning horizon. As a result, the estimation of returns to irrigation of land using land value observations in the recent decade may become considerably more complicated than in previous periods.

The other point to be addressed here is whether irrigation development per se accounts for any significant land value changes in off-farm areas. Cross-effects between newly irrigated land and potentially irrigable dryland will of course depend on the relevant crops grown, the availability of water, and the sizing of supply facilities, among other things.

There will be a tendency for off-farm areas both within and on the fringes of rural communities to experience some land value appreciation or at least a bolstering effect against outmigration influence. Most of the empirical work in this area, however, involves cases in which recreation or flood control and irrigation were co-objectives (e.g., see Knetsch; Ricci, Laessig, Glaser; Struyk; and Boodt). Most studies report on the extent to which local real estate markets are sensitive to the planning and implementing of reservoir projects. As a result there has been an emphasis on the analysis of time-series data relevant to property surrounding a reservoir or in the protected flood plain, as the case may be. Any study aimed at determining the extent of land value enhancement in areas further removed from lands receiving direct benefits will have to identify the linkages which are involved. In many instances a proximity linkage will be significant due to encroachment of an urban area into the irrigation project.

Such encroachment is very likely if water development is at the onset near a large metropolitan area such as the Tualatin Project (USDI Bureau of Reclamation) southwest of Portland, Oregon. However, the more representative irrigation projects are usually proximate to smaller communities whose growth potential may be affected by not only the normal income expenditure effects but perhaps also the possibility of implicit options for future water supply. Looking for the existence of these particular effects in land values is likely to require significant effort.

Economic Base Study Approach to the Analysis of Individual Existing Projects

One other major study approach needs to be mentioned. It focuses on the analysis of individual projects to trace out the interrelationships between irrigation developments and measures of regional economic growth, usually regional income, employment, or overall economic activity. There is also a long history to studies of this type. Some of the early work was reviewed by Kimball and Castle in 1963. More recent analyses are contained in the proceedings of a NRED symposium (USDA), in the study by Fullerton et al. cited earlier, and in work by Long, Nelson, and Potratz, in Idaho.

Most recent studies in this area employ input-output models. While this does not constitute a general equilibrium approach, these models allow a reasonably complete accounting of interactions in the economy and thus a comprehensive view of certain economic impacts from water developments. Whenever such models are employed, they generate estimates of positive impacts on outputs of certain other sectors of the local economy and of magnitudes for the various kinds of multipliers in excess of one. Note that this is a clear example of one of the cautionings about research provided in the presidental address at this meeting. Instead of making possible the test of a hypothesis, the mathematical specification of the model restricts the outcome of parameter estimates to a certain range. Economic analysts are, of course, not in agreement on the interpretation of the results of their analyses. Most of them are reluctant to make unequivocal statements about the use of the input-output parameters to derive economic impact estimates from irrigation developments or even from an existing irrigation project. This is not surprising. Given the very restrictive assumptions required for predictions from static input-output models, their use is defensible only for marginal changes in final demand. Major irrigation developments hardly ever have marginal impacts upon the economy of interest. What would be required is an identification of the structural changes which occurred in the economy as a result of the development. To derive such structural changes one would like to have input-output models for two states of the economy: with and without the irrigation development, but the same in all other respects.

Conclusion

Where does this leave us with respect to our ability to say something definitively about regional economic impacts from irrigation developments? Our review of the literature on this subject turned up no new arguments which would challenge the view that from the global viewpoint a special accounting of regional impacts is irrelevant except under special circumstances. Our discussion of the "local venture capital formation" hypothesis may enlarge slightly the set of the latter circumstances. From a local point of view, such impacts cannot be ruled out on logical grounds. The difficulty here lies in their empirical estimation.

We reviewed three approaches to the estimation of these impacts. As agricultural and resource economists we are naturally reluctant to discourage the profession from the study of agricultural and other land values. Yet the immediate payoff from the land value approach to this application does not appear promising. To make this approach productive would require not only a general understanding of farm land values but also the mechanisms by which agricultural productivity is translated into changing values for other real estate assets. Nevertheless, even limited success with this approach would shed light on certain distributional consequences associated with irrigation developments which are not likely to be discovered using other methods of analysis. We are thinking here about sharing benefits from these developments between the group of original residents in a community and those who may be attracted by the development.

The input-output approach has two strengths.

It lends itself to prediction of the regional impact of marginal changes in the level of irrigation development. The specificity of the estimates of the distribution of impacts may also facilitate the design of more comprehensive financing and cost-sharing schemes than are currently employed. It is going to be difficult to say very much about the overall magnitude of regional development impacts from this approach. Comparisons among input-output models to ascertain how the structure of a regional economy has changed because of the irrigation development are likely to be frustrated because of the violation of the *ceteris paribus* assumption.

It may be too early to abandon the multi-area statistical approach. While it has not distinguished itself in the past, there are no overwhelming conceptual difficulties with this approach. Data limitations appear to have been the effective constraints in the past. Additional resources should allow a sufficient data base to be developed. Most likely the study area would have to encompass more than one state and would require research cooperation and support from institutions in several states. We realize that there is not a long list of successful endeavors of this kind.

Finally, we anticipate that someone will question whether our analysis is the equivalent of building deck chairs for that famous ocean liner which sank after hitting an iceberg nearly seventy years ago. Even the casual observer of the federal interest in water resource developments will have perceived the end of an era. But even in the balance of a strong federal interest in new developments there is a growing program in the Bureau of Reclamation for "Rehabilitation and Betterment" of existing projects. Repayment capacity, not national net benefits, is the decision criterion for these federal expenditures. Furthermore, the states of Oregon and Washington recently have adopted loan programs for irrigation developments. Aside from these active roles in irrigation developments, the states will have to be equipped to make allocative decisions between irrigation developments (existing and potential) and competing water uses. There is likely to be a continuing interest in the comparative regional impacts of irrigation and other types of developments.

References

Barkley, Paul W. "The Economic Meaning of Water: Patterns in Variation." *Water and Community Development*, ed. Donald R. Field, et al., pp. 27–40. Ann Arbor, Mich.: Ann Arbor Science Publishers, 1974.

Beale, Henry B. R. "A Comparison of Evaluations of Four Irrigation Projects: Land Values and Budget Studies." *Growth and Change* 9(1978):2–28.

Boodt, William A., Jr. "Effects of Reservoir Recreation Development upon Rural Residential Property Values." Ph.D. thesis, Oregon State University, 1978.

Cicchetti, Charles J., V. Kerry Smith, and John Carson. "An Economic Analysis of Water Resource Investments and Regional Economic Growth." *Water Resour. Res.* 11(1975):1–6.

Fox, William F., Jerome M. Stan, W. Maureen Godsey, and Susan D. Brown. *Economics of Sizes in Local Government: An Annotated Bibliography.* USDA ESCS Rural Develop. Res. Rep. No. 9, Apr. 1979.

Freeman, A. Myrick, III, and Robert H. Haveman. "Benefit-Cost Analysis and Multiple Objectives: Current Issues in Water Resources Planning." *Water Resour. Res.* 6(1970):1533–9.

Fullerton, Herbert H., W. C. Lewis, J. C. Anderson, J. F. Keith, and R. Willis. *Regional Development: An Econometric Study of the Role of Water Development in Effectuating Population and Income Changes.* Utah Water Res. Lab. PRRBE 089-1, Utah State University, 1975.

Hamilton, Joel R., and Richard Reid. "Rural Communities: Diseconomies of Small Size and Costs of Migration." *Growth and Change* 8(1977):39–44.

Haveman, Robert H., and John V. Krutilla. *Unemployment, Idle Capacity, and the Evaluation of Public Expenditures.* Baltimore, Md.: Johns Hopkins University Press, 1968.

Kimball, N. D., and E. N. Castle. *Secondary Benefits and Irrigation Project Planning.* Oregon State University Agr. Exp. Sta. Tech. Bull. No. 69, May 1963.

Kneese, A. V. *Water Resources: Development and Use.* Kansas City, Mo.: Federal Reserve Bank, 1959.

Knetsch, Jack L. "The Influence of Reservoir Projects on Land Values." *J. Farm Econ.* 46(1964):231–43.

Lee, Warren F., and Norman Rask. "Inflation and Crop Profitability: How Much Can Farmers Pay For Land?" *Amer. J. Agr. Econ.* 58(1976):984–90.

Long, Roger B., Terry Nelson, and Clarence J. Potratz. "Secondary Impacts of the Boise Project of Idaho." Dep. Agr. Econ., University of Idaho, May 1978.

Major, David C. "Benefit-Cost Ratios for Projects in Multiple Objective Investment Programs." *Water Resour. Res.* 5(1969):1174–79.

———. *Multiple Objective Water Resource Development.* Washington, D.C.: American Geophysical Union Water Resour. Monograph 4, 1977.

Major, David C., and Roberto L. Lenton. *Applied Water Resource Systems Planning.* Englewood Cliffs, N.J.: Prentice-Hall, 1979.

Margolis, Julius. "Secondary Benefits, External Economies, and the Justification of Public Investment." *Rev. Econ. and Statist.* 39(1957):284–91.

Milliman, J. W. "Land Values as Measures of Primary Irrigation Benefits." *J. Farm Econ.* 41(1959):234–43.

Papageorgiou, G. J. "Agglomeration." *Rgnl. Sci. and Urban Econ.* 9(1979):41–59.

Powers, Roland C. *Identifying the Community Power Structure*. North Cent. Rgnl. Extens. Pub. No. 19, NCRS-5 Leadership Ser. No. 2. Iowa State University Cooperative Extension Service, 1975.

Renshaw, Edward F. "Cross-Sectional Pricing in the Market for Irrigated Land." *Agr. Econ. Res.* 10 (1958):14–19.

Ricci, Paolo F., Robert E. Laessig, and Edward R. Glaser. "The Preoperational Effects of a Water Resources Project on Property Prices." *Water Resour. Bull.* 14(1978):524–31.

Schramm, Gunter. "Regional Benefits in Federal Project Evaluations." *Ann. Rgnl. Sci.* 6(1972):84–95.

Selby, H. E. "Factors Affecting the Value of Land and Water in Irrigated Areas." *J. Land and Pub. Util. Econ.* 31(1945): 250–58.

Struyk, Raymond J. "Flood Risk and Agricultural Land Values: A Test." *Water Resour. Res.* 7 (1971):789–97.

Tweeten, Luther, and George C. Brinkman. *Micropolitan Development*. Ames: Iowa State University Press, 1976.

U.S. Department of Agriculture, Economic Research Service, Natural Resource Economic Division. *Secondary Impacts of Public Investment in Natural Resources*. USDA Misc. Pub. No. 1177, 1968.

U.S. Department of Interior, Bureau of Land Management. *Boise District Agricultural Development DEIS for Southwest Idaho*. Boise, Idaho, May 1979.

U.S. Department of the Interior, Bureau of Reclamation. *The Rehabilitation and Betterment Program*. Washington, D.C., Sep. 1978.

U.S. General Accounting Office, Comptroller General of the United States. *An Overview of Benefit-Cost Analysis for Water Resource Projects*. Washington, D.C., August 1976.

U.S. Inter-Agency River Basin Committee, Subcommittee on Benefits and Costs. *Report to the Federal Inter-Agency River Basin Committee: Proposed Practices for Economic Analysis of River Basin Projects*, rev. ed. Washington, D.C., 1958 (originally published in 1950).

U.S. Water Resources Council. "Principles and Standards for Planning Water and Related Land Resources." *Federal Register* 38, No. 174, 10 Sep. 1973, 24778–24869.

———. "Procedures for Evaluation of National Economic Development (NED) Benefits and Costs in Water Resources Planning and Proposed Procedures to the Standards for Planning Water and Related Land Resources." *Federal Register* 44, No. 102, 24 May 1979, 20194–30258.

Whittlesey, Norman K., and Walter R. Butcher. *Irrigation Development Potential in Washington*. Washington Agr. Res. Ctr. Cir. 579, 1975.

———. "The Social Overhead Costs of Water Resource Development." *Water Resour. Bull.* 15(1978):258–70.

Young, Robert A. "Economic Analysis and Federal Irrigation Policy: A Reappraisal." *West. J. Agr. Econ.* 3 (1978):257–67.

Returns to Public Irrigation Development and the Concomitant Cost of Commodity Programs: Discussion

Harold O. Carter

Martin addresses himself to what many economists as well as others have viewed for years as seemingly contradictory and inefficient government policies: namely, that the federal government has simultaneously supported the Bureau of Reclamation's water development, output-increasing activities and in Martin's words "effected commodity programs designed to reduce the supply of major agricultural commodities . . . ."

The underlying question being posed by Martin differs somewhat from what one generally would expect to encounter in considering this apparent contradiction. Most previous assessments of Bureau activity are specific to particular projects and use a standard benefit-cost framework of analysis. Benefit calculation assumes a perfectly elastic demand curve for commodities to be produced by the single marginal project being evaluated. One does not need great analytical ability to conclude that, generally, an acreage control program operating within the project area would be at cross-purposes at least in the short run, with respect to societal efficiency in the production of agricultural products. Martin, however, poses a different question. He is saying, essentially, what is done is done and is unlikely to be changed. But how do the aggregate costs and benefits of federal irrigation development over the past seventy-five years compare? And in aggregate, have federal projects really had a significant effect on commodity program costs? Quite rightly, Martin argues that while the elasticity of demand for agricultural output may be close to infinity for the Bureau's smallest, 221-acre project, it could not be infinite over all of its 9.3 million acres. Martin then formulates the conceptual framework for the problem in terms of the familiar Marshalian consumer-producer surplus paradigm with a downward sloping demand curve.

The empirical section of the paper presents some first approximations of consumer and producer surpluses, net of governmental costs both in irrigation development and for commodity programs. Conclusions of a tentative nature are drawn that viewing all past projects in the aggregate "rational economic arguments can be made on the basis of distributional gains to consumers even when netting out costs of national commodity programs." In fact, Martin states in the concluding section that the gains could be substantial if output were not restricted. Incidentally, this later claim appears to be at odds with an earlier statement to the effect that irrigation development was not a major culprit in surplus grain production except perhaps with barley.

Curiously, Martin attempts to extend into the future for current or on-line projects his analysis about the benefits and costs of all federal irrigation development. This, of course, gets us back to assessing the benefits and costs of the marginal project where the elasticity of demand approaches infinity. Some of the observations made by Martin seem quite valid but are not well-related to the primary thrust of the paper.

For the remainder of my comments, I want to elaborate on and emphasize some of the underlying assumptions made by Martin, most of which explicitly appear in the paper. Then I will comment on the methods and assumptions used in deriving the empirical approximation central to the main question posed in the paper.

Market Imperfection

The assumption of the downward sloping demand curve is crucial to establishing the existence of a positive consumer surplus. Equally

---

H. O. Carter is a professor in the Department of Agricultural Economics, University of California-Davis.

important is the implicit assumption of competitive markets in all stages of the food chain that allows consumers to reap the benefit from lower prices as the supply curve shifts to the right. Traditional pricing mechanisms are known not to be perfect for most commodities. Increased concentration in the farming sector is well known. Average farm size has about doubled in the last thirty years. Similarly, the number of food and kindred product manufacturing establishments declined one-third between 1958 and 1972 and increased in size. Grocery store chains with over 101 stores captured 29% of the sales in 1954, 40% in 1972. Because grain is heavily involved in government commodity programs, it should be noted also that best estimates suggest five major export firms account for well over 90% of U.S. grain exports.

If market concentration increases, the gains from irrigation development or any new technology can be captured by a small group rather than the general consuming public as the model implies. Unfortunately, we have little empirical information on which to judge the amount of consumer surplus captured through market imperfection. If the consumer loss is significant, the case is obviously weakened for a public subsidy to producers in the form of zero interest on irrigation project repayment charges, which is the past and current practice under reclamation law. And as Martin points out, if the original price is maintained through production controls, there is no consumer gain to provide a subsidy.

The Incremental Output from Federal Investment

In order to assess the extent of a possible commodity price decline from irrigation development, it is necessary to gauge the shift in the supply curve as well as the supply elasticities. Martin's approach is to estimate the implied incremental output from federal investment as a percentage of 1977 total U.S. production. This essentially involves an estimate of what Bureau land would produce farmed dryland, according to Martin, assuming the same cropping plan that exists with irrigation water. The difference between the implied dryland production (with irrigated crop plan) and the Bureau lands' current production is the increment from irrigation. Further, Martin assumes that cotton, dry beans, vegetables and melons, and orchards would not be grown in the absence of irrigation water which, in 1977, accounted for 3.5 million acres (about one-third of the Bureau's total acres). For these crops all of Bureau production is counted as the increment from irrigation. If I understand the procedure, the implicit assumption is that these 3.5 million acres remain idle without irrigation water rather than being planted to a dryland crop, say barley or wheat, when assessing the "before" and "after" situation. If we could assume that these 3.5 million acres were planted to dryland cereal crops in the "before" situation, the increment from irrigation conceivably could be negative for these particular cereal crops. On the other hand, as all good economists say, the irrigation water attributed to the Bureau resulted in greater production of cotton, beans, vegetables, and orchard crops probably at the expense of farmers in non-Bureau land. For example, some farmers in Alabama may have been forced out of cotton production and into a next best crop, say soybeans. What this lengthy and possibly confusing comment comes down to is to say that the agricultural economy is dynamic and adjusts to changing conditions both in and out of Bureau project areas. Measurement of the Bureau impact is even more complex (both on inputs and outputs) than what Martin's paper suggests using a simplified comparative statics approach. Accordingly, unless one can assess properly the dynamic "before" and "after" situation, little definitive can be said about the Bureau's impact on particular commodity programs, not to mention the other social and economic impacts (structural change in different regions). My impression is still consistent with Martin's contention that irrigation is not the major culprit in oversupply of cereal crops and the problem would exist without public irrigation. Probably of more importance has been technological change resulting from mechanization, hybrid seeds, and chemicals.

In summary, Martin has suggested to us that Bureau water projects in total can be evaluated in the context of a land-saving technological innovation in a general equilibrium framework. Proper assessment of the benefits and costs attributable to a single "innovation" are complex, as the literature attests, and empirical approximations are rough at best. Yet it is still worthwhile to make the attempt. We have a challenge to sharpen the methodology and refine the empirical analysis.

On Augmenting Community Economic Performance by New or Continuing Irrigation Developments: Discussion

W. Cris Lewis

Stoevener and Kraynick have offered a review of some of the considerations in identifying and estimating secondary benefits of irrigation and related developments and the proper role of those benefits in feasibility analysis. The issue is particularly timely for at least three reasons: (*a*) the much closer scrutiny being given to water resource investments by the federal government; (*b*) the importance of secondary impact estimation in impact statements concerning a range of federal government actions, especially in the West; and (*c*) the continuing use (and misuse) of the secondary benefit argument by local development officials to generate local support for water projects. With regard to the latter, such arguments often include exaggerated claims about the magnitude of the secondary impacts and, furthermore, usually offer no rationale for their role in logically supporting property tax financing.

As I see it, three questions are raised: (*a*) Do irrigation and related projects generate significant secondary benefits? (*b*) If so, how should these benefits be estimated or measured? (*c*) Once measured, should those benefits be included in benefit-cost analysis; and, if so, how? As a corollary, if they are not to be included in the benefit-cost ratio, as I and many others would argue, should they be reported separately so that the decisions regarding interregional wealth transfers might be made on a slightly more rational basis?

The paper focuses on the second question. It raises a variety of issues on the question of secondary benefits and reviews a number of relevant studies. The authors review three methods of secondary benefit estimation: (*a*) the econometric or statistical approach, (*b*) input-output analysis, and (*c*) the land value approach.

Although the authors "waffle" slightly in their evaluation, they apparently find significant value only in the input-output alternative. For example, they state:

> As agricultural and resource economists, we are naturally reluctant to discourage the profession from the study of agricultural and other land values. Yet the immediate payoff from the land value approach to this application does not appear promising.

On conventional statistical analysis, they argue:

> We do not want to appear excessively critical of the multi-area statistical approach to measure regional economic development impacts from irrigation investments. In the past, we have encouraged our own graduate students to practice their quantitative skills in this area. But the conclusion appears almost inescapable that this approach allows little to be said definitively about the phenomenon in question.

My evaluation of the relative merits of these three techniques would be just the reverse. The statistical or econometric analyses have been used to test countless hypotheses not only in economics but throughout the sciences. That they would not find significant application in questions revolving around the impact of water resource investment seems highly unlikely. To be sure, some of the data problems are severe, particularly in trying to measure the level of investment made in some small area, but these data problems pale into insignificance when compared to the data problems surrounding input-output analysis.

On an *ex post* basis, the land value approach must have significant theoretical merit. Certainly the value of irrigation investment should be capitalized in land values. To the extent that appropriate kinds of data can be developed on changes in land values of properties with and without new irrigation development, the land value approach ought to enhance our

W. Cris Lewis is a professor in the Department of Economics, Utah State University, Logan.

Utah Agricultural Experiment Station Journal Article No. 2478.

ability to measure the benefits of water resource investments.

With regard to input-output analysis, the strengths and weaknesses of that construct are well-known and need not be reviewed. Suffice it to say that as the spatial unit of analysis gets smaller, the questions regarding the use of input-output techniques become larger. The relative importance of external flows and the limited data availability combine to weaken the argument for its use. Stoevener and Kraynick also argue that because of the "specificity of the estimates," input-output analysis may "facilitate the design of more comprehensive financing and cost-sharing schemes than are currently employed." Frankly, the tremendous and, in some cases, excessive detail provided by input-output analysis tends to obscure the more fundamental questions on quality of those predictions.

For example, the assumption of constant coefficients of production, which we all know in economics to be untrue, leads me to believe that the predictions made by input-output analysis are likely to be wrong. It is simply not true that in production relations, the marginal and average functions are coincident. Furthermore, the input-output analysis may be well-suited to questions of prediction but has limited value in hypothesis testing on an *ex post* basis.

In conclusion, Stoevener and Kraynick have chosen a particularly appropriate time to review some of the important issues surrounding secondary impact measurement. The review should be useful in encouraging the necessary additional work on these questions, and, in that sense, the paper makes an important contribution. Unfortunately, they have not gone beyond a brief review of standard benefit measurement techniques, and further, I would disagree with the main thrust of their conclusions regarding the relative merits thereof.

Abstracts

Symposia

Commodity Price Forecasts: Experience and Accuracy. Gordon C. Rausser, chairperson (University of California, Berkeley), Dean Chen (Wharton Econometric Forecasting Associates), Richard E. Just (University of California, Berkeley), Ed Whitacre (Data Resources, Incorporated), and Abner Womack (CES, ESCS, USDA)

Commercial forecasts of spot commodity markets have been available for a number of years. These forecasts are quarterly, refer to specific cash markets, and cover a number of commodities. The firms that generate and sell these forecasts, largely to agribusiness companies, include Chase Econometrics, Data Resources, Inc. (DRI), Doane, and Wharton Econometric Forecasting Associates. The forecasts are based upon large-scale, U.S. agricultural sector models which specify formal links among individual commodities.

The purpose of the symposium was to compare and evaluate the price-forecasting experience and accuracy of these commercial venders from commercial, academic, and government perspectives. The first participants in the symposium, representing major econometric forecasting firms, described their service and clientele. They then discussed their forecasting records with the objective of illuminating the current contributions of large-scale econometric models and identifying where additional improvement is needed.

The second part of the program addressed the issue of accuracy of the major forecasts by computing selected measures of information content for the Chase, DRI, Wharton, and several other econometric firm forecasts of average quarterly cash market prices over the period 1976–78. The question addressed included the following. Does the comparative accuracy of different models depend upon the forecast horizon, e.g., is one more accurate for, say, a one-quarter forecast and another more accurate for a two-quarter or longer term forecast? What is the value of information provided by the econometrically based forecasts, and does this value compare favorably with those afforded by futures markets?

As a third part of the program, the large-scale forecasting efforts of the USDA were described and used as a backdrop against which to compare the commercial forecasting efforts, experience, and accuracy.

Variation of root-mean-squared errors among econometric forecasters was fairly large. Also, there was no clear dominance of one forecaster or vender over another when all horizons were considered. Over all commodities and horizons, the average rank for futures market forecasts was approximately 2.5 suggesting that, at the mode, the econometric models did not forecast as well as the futures markets. Finally, the composites of the econometric forecast and a futures market price were shown to be significantly more accurate than the individual component forecasts.

Agricultural Pollution: Are We Asking the Right Questions? Daniel W. Bromley, chairperson (University of Wisconsin), Klaus Alt (USDA, Iowa State University), Pierre Crosson (Resources for the Future), Gerald Horner (USDA, University of California, Davis), Tom Waddell (Environmental Protection Agency, Athens, Georgia), and Basil Sharp (University of Wisconsin)

Our national capacity to produce food and fiber in sufficient quantity to permit large agricultural exports has been facilitated by an artificial reckoning of the full social costs of domestic agricultural production. Can we continue to ignore environmental costs in order to maintain, or expand, our productive capacity?

The regulatory process has been one of seeking cooperation from farmers rather than mandating standards as in industrial and municipal discharges. If regulation becomes more stringent, do we have the analytic ability to offer guidance? Have we developed useful performance criteria? Have we seriously considered the regional and interregional issues inherent in a more concerted regulatory approach? Have we been sufficiently critical of the purported benefits of public participation programs?

Our models assume minimal institutional lag, perfect compliance, and few enforcement problems. Are our recommended policies consistent with the time perspectives of those formulating policy? Have we rigorously analyzed the incongruous policies that favor expansion onto marginal agricultural lands and yet call for reduced erosion?

These issues will require the attention of the best economists if national policy on agricultural pollution is to be coherent in scope and in content.

Needs and Strategies for Improving Graduate Training for Work in International Agricultural Development. Harold Riley, chairperson (Michigan State University), Darrell Fienup (Michigan State University), Kenneth Nobe (Colorado State University), and Russell Stevenson (Agricultural Development Council)

Fienup reported the results of the AAEA International Committee survey of LDC agricultural economists who have taken graduate work at U.S. universities and a related survey of U.S. professionals who, at the time they completed their graduate programs, were strongly oriented toward careers in

international development. The studies indicate that a high percentage of the LDC alumni have employment in the field of agricultural economics in their home countries and for the most part they have found their training to be useful and relevant. The demand for U.S. graduate training in agricultural economics is expected to continue at a high level, but several program modifications are being suggested to make the training more useful in the LDCs, especially in the least developed countries. Nondegree training, both in the United States and in developing countries with additional emphasis on research methodologies, planning, project evaluation, and public administration, are areas where alumni desire further training.

Although a high proportion of the young U.S. professionals surveyed have significant job involvements in international development, they hold the view that many of their peers are actually deserting this area due to the uncertainty of their positions and lack of support within universities.

The validity of the survey results and the possibility of additional analysis of the data were points of discussion in the symposium. There was a high degree of interest in the results of the surveys and several suggestions were made for strengthening graduate training both in the United States and in the LDCs. A publication summarizing the results of the study and a related set of recommendations will be available later this year.

Agricultural and Water Quality Improvement—What Are the Implementation Costs and Policy Issues? Lee A. Christensen, chairperson (ESCS, University of Georgia), George Casler (Cornell University), Edward Michaelson and David Walker (University of Idaho), John Miranowski (Iowa State University), Klaus Alt (ESCS, Iowa State University), and Lawrence W. Libby (Michigan State University)

This symposium dealt with costs and policy issues related to alternatives for agricultural nonpoint source pollution control and water quality improvement. Discussants highlighted research results, but focused on information needs.

Issues raised included the appropriateness of the term "best management practices" and whether the water quality problems addressed are properly defined, especially if too much focus is on erosion control as a surrogate for water quality improvement. More evidence is needed identifying the long-run benefits to farmers from erosion control and showing the relationship between reduced erosion on farmland and reduction in nutrients, pesticides, and sediment deposited in lakes and reservoirs.

More information is needed on the long-run effect of erosion control on yields, the effectiveness and yield effect of alternative tillage practices, and the measurement of benefits of increased water quality.

Research on erosion control in the wheat producing areas of the Pacific Northwest indicated that application at the farm level of a program of restricted summer fallow, minimum tillage, contour tillage, divided slopes, and seeding critical areas was more effective than a combination of changing crop rotations and relying on minimum tillage.

Another topic discussed was criteria for selecting appropriate policy instruments for controlling nonpoint pollution and how policy costs influence the choice of policy instruments. Important selection criteria needed for such alternative policy instruments as user charges, subsidies, marketable rights, and direct regulations are efficiency and equity. Choice among efficient options can be enhanced by minimizing the social cost of an error in the level of abatement. Greater attention needs to be given policy costs such as the costs of information, administration, and enforcement when establishing the optimum level of pollution abatement and selecting policy instruments.

Food Regulation. William T. Boehm, chairperson (ESCS, USDA), Tanya Roberts, Clark Burbee, and Chuck Handy (ESCS, USDA)

The discussants at this session presented the results of recent economic research in the food regulation area. A diversity of research methodologies was discusssed.

The origins of federal milk-marketing-order price regulation of close substitutes for fresh drinking milk were discussed by Tanya Roberts. The regulations now make these substitutes (such as reconstituted milk) subject to a tax equal to the Class I-Class II price. Roberts concluded that the congressional and judicial branches of the U.S. government were not involved in that decision. The actions ultimately taken by the administrative branch were initiated by cooperatives supplying the drinking milk market. All other economic interest groups potentially affected by the rule opposed it.

Handy investigated the economic impact of a proposed change in weight labeling for meat and poultry. After conducting tests to determine the amount and variability of liquid in chicken packages under alternative regulatory options, he concluded (*a*) alternative net weight rules would not affect the real price per pound, (*b*) the proposed rule would enable consumers to make better per pound price comparisons, and (*c*) industry would incur costs of \$59 to \$116 million for improved quality control.

Burbee and Boehm analyzed the economic effects of banning the use of sodium nitrite as a meat-curing agent. As a consequence of such a ban, food prices probably would increase, reflecting the somewhat higher costs of pork processing, lower hog production, and increased demand for other meats. Net income from farming would also be lower. The All-Food CPI would be 0.3% to 0.7% higher.

AAEA Annual Agricultural Outlook Survey. Glenn Nelson, chairperson (University of Minnesota), Gene Futrell (Iowa State University), John Ikerd (Oklahoma State University), Glenn Grimes (University of Missouri), Charles Erickson (Cargill), and Gary Benjamin (Federal Reserve Bank of Chicago)

This symposium was based on information provided by the AAEA membership in the second annual survey of agricultural outlook. Estimates of supplies and prices were included for the years 1979 and 1980 for the major agricultural commodities including both livestock and crops. Outlook information also was summarized for agricultural costs and returns and for selected general economic indicators.

The symposium began with a review by Futrell of results from the first AAEA outlook survey in 1978 as compared to subsequent actual events. In general, actual prices so far in 1979 on livestock, poultry, and crop items have averaged above forecasted levels, and actual net farm income is also above the forecasted level.

Ikerd presented an overview of the procedures used in the 1979 survey and the characteristics of respondents. The detailed results of the survey were discussed by Grimes, Erickson, and Benjamin who also gave their personal views of the outlook. A major portion of the symposium was devoted to open discussion among the speakers and others attending the symposium.

Are Agricultural Markets in Disequilibrium? Robert G. Chambers, chairperson (Ohio State University), G. S. Maddala (University of Florida), L. Joe Moffitt (USDA), Richard E. Just (University of California, Berkeley), and Robert D. Emerson (University of Florida)

In recent years there has been an increasing amount of attention given to the formulation and estimation of disequilibrium econometric models. These models attempt to portray markets that do not always clear in the neoclassical sense; phenomena that are particularly characteristic of markets that are subject to minimum (maximum) price or quota regulation. Existing models that have failed to take this aspect of the modeling problem into account will in most cases be inconsistently estimated and, thus of little practical value for policy analysis. It is important, therefore, to identify the most important aspects of disequilibrium models and how they apply to agriculture.

Maddala (presented by Emerson) focused on a theoretical review of the literature on disequilibrium econometrics while discussing several modifications of the standard models which may be appropriate for such agricultural markets as the various futures markets. Chambers and Just discussed their experience in applying disequilibrium techniques to the U.S. beef import market, the California retail milk market, and the U.S. cattle industry. Moffit reported some very interesting results he has obtained in modeling the market for gasoline in a disequilibrium framework while emphasizing some important findings on agricultural demand for gasoline.

Curriculum—Meeting the Needs of Our Changing Clientele. Carl O'Connor (Oregon State University) and Raymond J. Folwell, cochairpersons (Washington State University), E. Bruce Godfrey (Utah State University), Daniel D. Badger (Oklahoma State University), Thomas A. Brewer (Pennsylvania State University), and Howard Madsen (General Foods)

The major emphasis of the symposium was on student needs in a curriculum, given present employer expectations. The specific topics were: (*a*) curricula requirements ane marketable skills; (*b*) intern and/or trainee type experiences; (*c*) the needs of the farm and nonfarm student; and (*d*) the skills sought by potential employers.

Arguments can be given for general and specialized curricula and most agricultural economics curricula contain both elements. The greatest need in most departments is neither more theory nor specialized classes, but increased use of a set of marketable skills that apply the principles of economics. An applied curricula is difficult to obtain, however, because it requires imagination, is time consuming, and offers relatively little reward when compared to other efforts.

For the student to compete effectively in the job market in the 1980s, agricultural economics majors will need increasing opportunities for intern and/or trainee experiences. A poll of twelve universities in the Southwest and Midwest indicated that such opportunities are expanding. Many benefits accrue to student participants. Coordinating with employers and supervising the intern participants requires considerable faculty time. The internship program, a well as curricula, must be modified in accordance with the background of the students and the farming and agribusiness communities in the locale of the university. The skills sought in agricultural economics majors are those of basic economics, management, and communication skills.

Will Large Dairy Farms Be the Most Effective in the Future? John W. Wysong, chairperson (University of Maryland), Bernard L. Erven (Ohio State University), Gayle S. Willet (Washington State University), John Holt (University of Florida), and Sherrill B. Nott (Michigan State University)

Entrepreneurship and capital availability together with dairy production, marketing, and input acquisition know-how have been major factors in the development of large dairies in some southern areas of the United States. The objectives of increased managerial income flows and enhancement of financial asset stocks and income flows have been of greater concern than attempts to minimize costs

per unit of revenue generated. Substantial opportunities for economic gains have existed in selected areas from economies of feed procurement and preferential milk marketing arrangements for large dairy farms once major per unit cost reductions have been attained.

Recent data on modern milking systems indicated that this cost component averaged only 12% of total milk production costs, and the major cost reductions could be attained by herds of 100 to 200 cows (although some cost reduction of the one-man milking systems studied occurred up to the 500-cow level). The newer, more labor-efficient milking systems with high cow milking capacity per hour have higher investment costs which require large aggregations of milk cows at one feeding, milking, and housing site to reduce per cow costs to levels comparable to the smaller capacity milking systems. Major gains were available from use of automatic teat-cup detachers irrespective of size and design of the milking system.

The problems of cow management on large dairy farms are compounded with increased problems of labor management in the areas of recruitment, retention, labor relations, labor productivity, salary and wage determination, and other financial and nonfinancial worker incentives. Labor training has tended to be a short-term apprenticeship arrangement on the actual employing dairy farm firms.

No consensus existed on the question of possibilities for greater crop or livestock specialization in major milk production areas. This is an area of future needed research to determine potential gains in human resource productivity and in net value added per employee.

Foreign Aid Reorganization and the Profession. Charles E. Hanrahan, chairperson (ESCS, USDA), Nicolaas Luykx (Institute for Scientific and Technological Cooperation, IDCA), Quentin West (Office of International Cooperation and Development, USDA), Morris D. Whitaker (Board for International Food and Agricultural Development, IDCA)

The U.S. foreign aid program is being reorganized with the creation of an International Development and Cooperation Administration as the policy-making entity for U.S. foreign assistance. IDCA's director will report to the President. IDCA groups into one agency, AID and the Institute for Scientific and Technological Cooperation (ISTC), a newly established agency which has responsibility for research collaboration between the United States and research institutes in other countries. This reorganization has potentially important implications for the participation of the agricultural economics profession in U.S. development assistance programs.

Among the most promising aspects of the reorganization is the establishment of the ISTC, which agency offers the possibility of direct institution-to-institution collaboration in research, training, and extension, traditional activities of agricultural economics departments in the Land Grant system. Linking the Joint Committee on Research of the BIFAD to the ISTC could enhance the research role of the colleges of agriculture in U.S. agricultural development programs. Some skepticism was voiced by university and USDA agricultural economists about the effectiveness of the reorganization in dealing with what they identified as a fundamental problem with the U.S. agricultural development program: an inadequate supply of agricultural economists with training and experience in international development, declining opportunities for professional involvement in international development, a serious reduction in the number and quality of agricultural technicians and scientists in AID, and a limited ability of the foreign aid agency to transfer and/or build technical capacity for carrying out agricultural development in LDCs.

Great Plains Droughts: Are There Effective Management Strategies? Wayne D. Rasmussen, chairperson (USDA), J. Eleonora Sabadell (Department of the Interior), Donald A. Wilhite (University of Nebraska), and Marvin Duncan (Federal Reserve Bank of Kansas City)

The formal presentations represented an interdisciplinary summary and evaluation of a three-day symposium held at the University of Nebraska under the leadership of Norman Rosenberg. Rasmussen reviewed past impacts of drought and said that the report of the Great Plains Committee in 1936 set criteria by which programs still may be judged.

Sabadell listed thirteen major factors presently contributing to vulnerability to drought. These related mainly to water use, energy, changing soil quality, and program management.

Wilhite discussed how technology might be divided into short-term or reactive strategies and long-term or drought-proofing measures. He emphasized innovative technologies that would better utilize available moisture.

Duncan pointed out that many firms and communities have underestimated their vulnerability to drought. This has hindered both planning and the building of flexibility into economic systems at all levels to deal with drought problems.

In a wide-ranging discussion with a number of participants, present federal programs, the usefulness of innovative technologies, and current farming practices were attacked. Crop diversification, careful management of water for irrigation, and a reemphasis on soil conservation were urged. There is a need to reconcile the economic interests of the individual firm and of the nation.

Is Integration of Research and Extension Possible? Marilyn H. Grantham, chairperson (Virginia Polytechnic Institute and State University), Russell C. Youmans (Oregon State University), William R.

Lassey (Washington State University), and Kenneth R. Terfertiller (University of Florida)
Title V of the Rural Development Act of 1972 mandated a joint research/extension effort through the land-grant universities intended to address the most serious and difficult to handle long-standing problems of the rural areas of the United States. The development of Title V work in the respective states resulted in many diverse kinds of specific efforts. However, the common thread throughout was the attempt to integrate or link together the research and extension phases of the work being done. Participants in the discussion reflected upon their respective experiences with Title V Rural Development efforts. Some of the reflections were that although integration of research and extension can be stopped by legislation, it cannot be created solely by legal means and that integration has been easier on the extension side, possibly because there are more rewards for the extension professional in carrying out his efforts than for the researcher. Some of the suggestions offered for accomplishing integration of research and extension were choosing personnel with sufficiently similar backgrounds to be able to interchange roles, developing personnel capabilities in order for them to serve as linkers between researchers and extension educators, and establishing a responsive administration structure and sufficient level of supplemental state funding to insure that rural development is given the impetus to occur.

Applications of Economics in Plant and Animal Breeding. George W. Ladd, chairperson (Iowa State University), Bryan E. Melton (University of Florida), Gerald A. Carlson (North Carolina State University), A. Steven Englander (Yale University), and Robert E. Evenson (Yale University)
Melton summarized some basic concepts and relations used in animal breeding and discussed selection of animals for breeding programs. One means of selection is a selection index, whose construction reaquires the use of economic values of traits. Economic value measures effect on profit of improvement in a trait.

Melton and Ladd presented two procedures for measuring economic values of traits. The procedures start with an "interdisciplinary production function": one containing quantities and characteristics of inputs. They reported an empirical application to beef cattle.

Carlson reported a study of market prices of dairy bulls' semen. One feature of breeding is the uncertainty in transmission of traits to offspring by an individual parent. He found prices to be positively related to expected gain in milk value, and negatively related to uncertainty in milk value gain.

Englander and Evenson considered economic issues that arise from variable environments and interactions between invironments and genotypes. They presented a model for determining efficient locations of experiment stations, and for selecting and screening the results of a crop improvement program, and presented measures of some variables needed to apply the model.

Are Fisheries Economists Asking the Right Questions? Richard C. Bishop, chairperson (University of Wisconsin), Daniel R. Talhelm (Michigan State University), Nancy E. Bockstael (University of Rhode Island), John P. Nichols (Texas A&M University), Richard Marasco (National Marine Fisheries Service, Seattle), and Frederick J. Smith (Oregon State University)
Talhelm pointed out that recreational fishing demand analyses should give more attention to defining recreational products. Analyzing recreational supplies from the consumer's point of view holds much promise as a way of identifying different products. Bockstael suggested that current commercial fishing research is overemphasizing work related to Fisheries Management Plans. Too much attention is being directed toward descriptive details and too little toward theoretical and methodological research. According to Nichols, not enough questions are being asked on the marketing side. Industrial organization research, cost and efficiency studies, and demand and market development analyses are badly needed. From the National Marine Fisheries Service perspective, Marasco stated that too many past economic studies have been overly general and preoccupied with optimization. Specific studies dealing with such issues as the benefits and costs of regulations, how to manage for risk and uncertainty, and transboundary problems should receive higher priorities. Smith argues that rather than "spoon feeding" information to clientele groups, marine extension programs should focus on the true goal of education, to prepare people to better control their own destinies by teaching new skills, developing talents, and providing new knowledge to help them deal with their economic environment.

Federal Water Policy Reform and Its Implications for Irrigated Agriculture. Leonard Shabman, chairperson (Virginia Polytechnic Institute and State University), Harold Stults (ESCS, USDA), Arnold Miller (OPBE, USDA), Robert Young (Colorado State University), and Norman Whittlesey (Washington State University)
Federal water policy reform proposals of the Carter administration were discussed. Particular attention was paid to revised guidelines for estimating irrigation benefits, the focus of the policy reforms on water conservation, and the likely changes in water costs to irrigation farmers as a result of the policy changes. Revised evaluation procedures can result in improved estimates of the irrigation benefits of new projects. Changes in cost-sharing and repayment policy will have little effect on prices paid by

irrigators and, therefore, little effect on water use in agriculture or the politically expressed demand for new projects. The concept of water conservation will need further clarification to be a useful policy tool.

The discussion focused primarily upon traditional federal water project construction activities. Concern was expressed that the water policy reforms should have focused less on traditional project construction programs and more upon emerging issues such as integrating water quantity and quality planning and economic adjustments to declining groundwater tables. There was a consensus that agricultural economists should continue to do sound analyses of water projects, programs, and policies. Such analyses can provide an analytical basis for improved social decisions even though the specific recommendations from such research often appear to be ignored.

Agricultural and Food Policy Education: Is the Profession Meeting the Needs of Its Clientele? B. H. Robinson, chairperson (Clemson University), R. G. F. Spitze (University of Illinois), D. M. Hoover (North Carolina State University), J. B. Wyckoff (Oregon State University), and R. J. Hildreth (Farm Foundation)

The speakers felt that the profession had been meeting the needs of the clientele groups as evidenced by such indicators as the expanding cadre of professional policy workers and the number of both scholarly publications and policy publications addressed to lay audiences. However, each pointed to weaknesses in our current policy education programs. There seemed to be consensus among the speakers that the events of the current decade had stimulated a shift in the demand for policy education. The shift seemed evident irrespective of the clientele group.

Spitze proposed three major areas in need of remedial attention in graduate education: (*a*) training in public policy theory, (*b*) participatory experience in policy critique and dialogue, and (*c*) organized instruction in analysis of policy alternatives.

Hoover argued that undergraduate instruction should include analysis of the aggregate impacts of policy decisions to stress the societal relevance of economics and potential conflicts between private and social optima. He also stressed the need to build on the management aspects of policy decisions to enlist student interest. Hoover feels that policy instruction should be kept simple.

Wyckoff noted that the most successful extension policy-education programs have involved agents in the planning process. The participatory experience in extension education programs was noted by Spitze as a deficiency in graduate education.

The basic policy education model is similar for all clientele. The discussions suggested that educators can benefit from the successes and failures experienced by others irrespective of their primary clientele.

The Impacts of the Proposition 13 Movement. Dale Colyer, chairperson (West Virginia University), James Cothern (University of California, Davis), Phillip Gardiner (University of California, Riverside), Harold Guither (University of Illinois), and James Hite (Clemson University)

Proposition 13 in California has lead to movements to limit taxes and government spending. The movement surfaced from dissatisfaction with such matters as constantly rising taxes, feelings of waste in government, and lack of confidence in public agencies. Tax limitations are not new. Specialized limitations such as use value assessments, circuit breakers, homestead exemptions have been passed by many states in recent years. During the thirties, several states including Washington and West Virginia passed general property tax limitations. Examinations of such laws indicate three broad effects: reduced services, substitute taxes, and shifting of responsibilities to state levels. The initial impacts tend to be mitigated through time but some persist. Once passed, the limitations are not apt to be repealed due to their popularity. In states such as California the impacts may be lessened or postponed due to used surpluses to replace local collections. Immediate impacts included reduced public employment, reductions in school programs, and no pay increases. In some states, a rate limitation actually may result in increased taxes as assessment levels are raised from fractional to full market values. Proposition 13 also has been symbolic, causing legislative and administrative bodies to reevaluate tax and expenditure plans due to apprehension that public action will result in such restrictions.

Commodity Pricing Systems: Issues and Alternatives Bruce W. Marion, chairperson (ESCS, USDA, University of Wisconsin), V. James Rhodes (University of Missouri), Marvin L. Hayenga (University of Wisconsin), Lee F. Schrader (Purdue University), Dennis R. Henderson (Ohio State University), Thomas L. Sporleder (Texas A&M University), and E. Dean Baldwin (Ohio State University)

The three papers presented at this symposium examined current commodity pricing issues and possible solutions. The experience and recommendations of the Secretary of Agriculture's Meat-Pricing Task Force were reviewed by Rhodes, a member of that task force. Hayenga and Schrader discussed formula pricing in five commodities (beef, pork, cheese, turkeys, eggs), including the extent of an incentives for formula pricing and the benefits and

problems derived form formula pricing. The final paper examined the feasibility and impact of electronic markets, particularly in thinly traded or poorly performing markets. The three papers have been published as NC-117 Working Paper 39, Department of Agricultural Economics, University of Wisconsin-Madison.

Editor's note:
Abstracts for publication in the *Journal* were not presented for two symposia sessions: "Emerging Rural Employment Policy Issues," and "Teaching Decision Making under Risk and Uncertainty," led by Lee Bawden (Urban Institute) and J. Roy Black (Michigan State University), respectively.

Abstracts

Contributed Papers

Research Methods (Robert L. Christensen, University of Massachusetts, Chairperson)

"Six Alternative Methods for Linking Normative and Positive National Agricultural Models." Wen-Yuan Huang and Reuben N. Weisz (ESCS), Kenneth H. Baum (Virginia Polytechnic Institute and State University), Lloyd Teigen (ESCS), and Earl O. Heady (Iowa State University)
This paper discusses the pros and cons of six alternative procedures for linking normative and positive U.S. agricultural policy analysis models. A current experiment interfacing the CED Cross-Commodity Forecasting System with the ISU linear programming model is described.

"The Preference of Purchases Data over Sales Data in Primary Data Input-Output Models." Edward E. Ives (Ohio State University and Ohio Agricultural Research and Development Center)
Five arguments are made, based on statistical properties of estimated direct coefficients and the relative ease of handling certain other difficulties, that purchases data are preferable to sales data for generating primary data input-output models.

"Comparing Polynomial and Rational Lag Models." L. J. Butler and S. R. Thompson (Michigan State University)
This paper compares and attempts to evaluate polynomial and rational lags, both theoretically and empirically, by estimating the same lag structure both ways. Comparison is achieved by eliminating the unknown nature of the lag by using data generated from a simple economic model of known lag.

"Elasticities and Flexibilities in Systems of Simultaneous Equations." Jean-Paul Chavas (Texas A&M University), Zuhair Hassan (Statistics Canada), and S. R. Johnson (University of Missouri)
The interrelationships between elasticities and flexibilities have not been given a solid basis for interpreting applied results. The paper provides a derivation of the price and quantity responses obtained in linear simultaneous equation market models. It shows that, abstracting from estimation problems, the connection between price flexibilities and price elasticities can be made so as to allow an unambiguous interpretation of applied results.

"Information, Option, and Existence Value." Jon M. Conrad (Cornell University)
An intergenerational model of resource development is constructed to examine the concepts of option and existence value. These concepts are seen to relate to a more fundamental concept: the expected value of perfect information. The analysis would suggest that when sequencing irreversible resource developments both uncertainty and the expected value of information should be considered.

Policy, Concepts and Conflicts (Frederick L. Leistritz, Texas A&M University, Chairperson)

"An Analysis of U.S. Dairy Price Supports Based on Parity Versus Cost of Production." Andrew Novakovic (Cornell University) and Emerson Babb (Purdue University)
Analyses based on a spatial model of the U.S. dairy sector indicate that the current parity based price supports could lead to large and increasing federal expenditures on dairy products over a five-year period, whereas support prices based on the full cost of production would imply much lower expenditures.

"Measuring Farm Operators Nonfarm Wealth (or, Where Has All the Money Gone?)." Dean W. Hughes (USDA, Texas A&M University)
The "Balance Sheet of the Farming Sector" makes no attempt at reporting the nonfarm equity position of farm sector participants. This study estimates the size of such holdings for farm operator families and finds them to be significant, conservatively accounting for about 20% of reported assets in 1977.

"Prices Paid Indexes for Major U.S. Crops." Ed Fryar and James P. Houck (University of Minnesota)
Commodity-specific Prices Paid Indexes and Prices Received/Prices Paid ratios are calculated for corn, cotton, soybeans, and wheat. These indexes are then compared to the current USDA Prices Paid Index and Prices Received/Prices Paid ratios. Target prices are recalculated using the commodity-specific Prices Paid Indexes and then compared to the actual target prices for the 1976–78 period.

"Conflict within a Changing National Agricultural Policy-Making Process: Major Agricultural Legislation in 1977 and 1978." Jerry R. Skees (Michigan State University)
The new macropolitical dimensions of agriculture and food policy have resulted in an increase in the number and diversity of groups involved in the national policy-making process and in the potential for conflicts. This paper examines the political dynamics of the development of major agricultural legislation in 1977 and 1978, with particular attention to where the potential for conflicts existed and how they were resolved.

"Discontinuous Policy and Distorted Choices: The Case of Acreage Control." Robert D. Weaver (Pennsylvania State University)

Past acreage response studies have failed to recognize that government control policies have typically introduced taxes and subsidies which are discontinuous over acreage planted. The nature of this discontinuity is reviewed and its impact on profit maximizing choice analyzed. A general model suitable for econometric estimation which would accommodate this discontinuity in policy is introduced.

Teaching and Information Delivery (Kelso L. Wessel, Ohio State University, Chairperson)

"Editorship Location and Authorship Affiliation in the AAEA *Journal*." Rod F. Ziemer and Kostas G. Stamoulis (University of Georgia)

This paper presents an analysis of the relationship between editorship location and the distribution of authorship affiliation in the AAEA *Journal*. Nonparametric test results indicated that changes in editorship location have been accompanied by significant changes in the distribution of authorship affiliation over the period 1944–78.

" 'Hands-On' Models: Innovations for Teaching Economic Theory to Undergraduates." Josef M. Broder (University of Georgia)

The abstract nature of economic theory creates challenges for introductory agricultural economics courses. Current techniques designed to teach theory tend to be labor intensive or prohibit active participation in learning theory. This paper discusses recent experiences of designing, constructing, and presenting multiple dimensional and mechanical models into classroom learning.

"An Alternative Method for Training Non-English Speaking Students." Wilmer M. Harper and Martin J. Blake (New Mexico State University)

This paper evaluates a program designed to permit international students with English deficiencies to begin their graduate training while simultaneously taking an intensive course in English as a second language. The results indicate no significant performance difference for students in this program compared to students beginning training with English capabilities.

"An Intermodal Delivery System for Agricultural Marketing and Weather Data." Larry D. Jones and Joe T. Davis (University of Kentucky)

A project entitled "Green Thumb" has been initiated in Kentucky to provide farmers real-time weather and marketing data. This project represents a major departure from past dissemination systems in that it provides for rapid, continuous transmission of data directly to farmers' homes, utilizing computers, telephones, and television to access and deliver data.

"Budgeting the Impact of Dairy Investments." Gerald D. Schwab and Sherrill B. Nott (Michigan State University)

A whole farm budgeting and cash flow analysis of sixty-cow and 100-cow dairy farms investing in new barn and milking facilities is reported. At medium investment levels, a sixty-cow farm would need eighty cows or 15,000 pounds of milk per cow to maintain profit levels.

Livestock Management (Brent Spaulding, University of Arkansas, Chairperson)

"Estimating Learning Benefits from Research and Development in Anaerobic Digestion Systems for Animal Waste Disposal and Energy Recovery." James L. Anderson, Jr. (University of California-Davis) and Marilyn A. Altobello (University of Connecticut)

Learning functions relating cumulative investment in research in anaerobic digestion systems and costs of methane production are estimated and used to determine breakeven points for animal production units adopting this technology, potential net benefits, and regional distribution of benefits. Results indicate greatest benefits accruing to large-scale units in cattle-feeding states.

"Alternative Cost-Sharing Arrangements to Induce the Adoption of Improved Manure Handling Techniques: An Empirical Study." Douglas Southgate, Basil M. H. Sharp, Steven Lovejoy, and Nicolaas W. Bouwes, Sr. (University of Wisconsin)

In this paper, empirical observations constitute the basis of a model of farm operations. The model is used to estimate the minimum cost-sharing rate necessary to induce farmers to implement less-polluting manure management systems. The estimated rate is considerably below rates offered by current cost-sharing programs.

"Taking Account of Variation in Feedstuff Nutrient Values and in Animal Requirements in Ration Formulation." Neal Peterson, J. Roy Black (Michigan State University), and Danny G. Fox (Cornell University)

Choice of safety factor to use in formulation of rations for growing and finishing cattle is discussed. The subtraction of a nutrient's standard deviation from its mean for each feedstuff is superior to adding a safety factor to the animals' requirements for the nutrient. Appropriate safety factors, when the objective is to minimize expected (in a probability sense) cost, are .67, 1.1, and 1.2 standard deviations for 500-, 700-, and 900-pound average framed cattle, respectively.

"The Role of Market Price-Weight Relationships in Optimal Beef Cattle Management Models." Steven T. Buccola and Warren B. Jessee (Virginia Polytechnic Institute and State University)

Optimal beef cattle diet and rate-of-gain analyses normally ignore the relationship between the animal's market price and its weight. Theoretical and empirical models are developed to show that optimal daily weight gain tends to be less than the feasible maximum when market price per pound falls rapidly with weight increases.

"The Suboptimality of the Beef Cycle." Greg Hertzler and James H. Cothern (University of California-Davis)
The supply of beef is investigated using spectral analysis. The two and one-half year lag from herd build up until production is realized requires decisions based on future prices. Producers react instead to past prices, and the cycle results. Optimal control applied to an investment model shows the cycle to be suboptimal.

International Agricultural Production (T. Kelley White, Purdue University, Chairperson)

"An Analysis of Factors Affecting the Limited Utilization of Dry Season Irrigation in Northeast Thailand." Joe T. Davis, Russell H. Brannon (University of Kentucky), and Charles T. Alton (Kentucky Development Cabinet)
Although the government of Thailand has made substantial investment in irrigation infrastructure in northeast Thailand, there is still relatively little dry season irrigated farming being carried out in that region of the country. This study investigated the characteristics of dry season farming and farmers and suggested and tested some hypotheses for explaining this low utilization of dry season irrigation.

"Mitigating the Effects of Multicollinearity Using Exact and Stochastic Restrictions: The Case of an Aggregate Agricultural Production Function for Thailand." Ron C. Mittelhammer, Douglas L. Young, Damrongsak Tasanasanta, and John T. Donnelly (Washington State University)
Mixed estimation and OLS were each used to estimate an aggregate agricultural production function for Thailand for which data were highly multicollinear. The final mixed model obtained using minimax regret in the pretest appeared to outperform significantly OLS in terms of precision and overall reasonableness, mitigating a serious multicollinearity problem.

"The Potential for Self-Sufficiency in Food Production in Six Latin American Countries: Some Projections for 1985 and 1990." Marshall A. Martin and Anoosh Noori Esfandiari (Purdue University)
Based on the assumptions and empirical results of this study, most Latin American countries, with the possible exception of Argentina and Colombia, will find it impossible to become self-sufficient in food production in the 1980s. Fertilizer and food imports will be required in most Latin American countries.

"The Philippines Agricultural Sector in 2000 A.D. Result from the MAAGAP National Model." David E. Kunkel, Gil Rodriguez, Jr., and Leonardo A. Gonzales (ESCS, Republic of the Philippines)
A mathematical programming model of the Philippine agricultural sector was used to look at alternative scenarios for the year 2000. Model results indicated an expanding agricultural sector able to meet the needs of the Philippines. However, improved technologies for corn, feed grains, and vegetable crops are required if higher relative prices for these and livestock products are to be avoided.

"Examining Productivity Differences and Identifying the Efficient Farm Size: A Brazilian Example." James R. Sieber and Douglas L. Young (Washington State University)
Examination of Brazilian data over farm size classes revealed substantial variation between observed and theoretically efficient (implied by econometric production functions) input combinations and average costs. Given the likely persistence of imperfections preventing achievement of theoretical efficiency, use of an "empirically efficient" farm size identified by proposed procedures is encouraged.

Risk and Firm Growth (Robert E. Lee, A. D. Little, Chairperson)

"Firm Growth and Survival Versus Income and Cash Flow: The Influence of Land Appreciation." Larry J. Held (University of Wyoming) and Glenn A. Helmers (University of Nebraska)
A financial simulation model was developed to study the influence of land appreciation upon a Nebraska wheat farm. Results showed sizeable tradeoffs between increased firm growth and survival versus lower net income and larger cash flow deficits at higher rates of appreciation, raising serious questions regarding management goals.

"Effects of Different Measures of Dispersion on Risk-Efficiency Farm Plans in a MOTAD Framework." Tillak Persaud and Harry P. Mapp, Jr. (Oklahoma State University)
In this paper variations in net returns were measured in terms of deviations from the mean of the series and negative deviations from equally- and unequally-weighted moving averages in a MOTAD framework. Results indicate that differences in production activities, expected net returns, and relative variability of the farm plan occur depending upon the method used to measure dispersion of net returns.

"Risk-Returns Criteria in Selecting Farm Machinery." William Edwards and Michael Boehlje (Iowa State University)
Risk preferences can be introduced into machinery selection by estimating the mean and standard deviation for total costs, including timeliness costs,

associated with various machinery sets. Risk-returns criteria tested included *E, V* and *E, S* frontiers, cost-variance, upper confidence limits, and maximum affordable cost.

"A Return-Risk Analysis of the Decision to Participate in Government Price Support Programs." Eddie H. Kaiser and B. H. Robinson (Clemson University)
Farm planning decisions have been subjected to increasing risk and uncertainty during the last decade. Recent government farm programs have been designed to reduce instability in prices and supplies. This study employs MOTAD models to analyze the risk associated with alternative farm plans and the risk-reducing contribution of government farm programs.

"A Simulation Study of the Effects of Credit Terms Upon Maximum Feasible Farm Debt Burdens." Jerry Thompson and Greg Hanson (University of Minnesota)
Cash income data obtained from farm records is decomposed with a regression technique suggested by portfolio theory. Farm debt structure is simulated and maximum feasible relative debt burdens are estimated for several one- and two-enterprise farm types. Sensitivity of the maximum debt burdens to changes in credit terms is explored.

Energy Resources (Michael Hanemann, University of California-Berkeley, Chairperson)

"An Economic Feasibility Study of Crop Residues as an Auxiliary Fuel Source for Iowa's Coal-Fired Power Plants." Burton C. English, Cameron Short, and Earl O. Heady (Iowa State University)
The costs of crop residue for direct combustion in power plants are estimated in 1975 prices. These costs are incorporated into an Iowa agricultural linear programming model. This model is used to evaluate the impacts of energy price increases and increased sulfur restriction levels on the feasibility of crop residues.

"Impacts of Fuel Pricing and Nonprice Allocation Scenarios on High and Low Risk Crop Producers." Douglas C. Farthing (Texas A&M University) and James B. Kliebenstein (University of Missouri)
The study summarizes, through use of a quadratic program, the impacts of government nonprice fuel allocation levels versus fuel price increases on high and low risk crop producers. For high risk crop-producers fuel price increases had little or no impact on their fuel usage levels. Both fuel prices and nonprice allocation strategies were effective in cutting fuel usage by low risk producers.

"The Demand for Natural Gas and Electricity for Nine Northeastern States in the Residential, Commercial, and Industrial Sectors." James G. Beierlein (Pennsylvania State University), James C. McConnon (Iowa State University), and James W. Dunn (Pennsylvania State University)
Classification of energy demand into groups with homogenous uses and motives and the use of simple demand theory resulted in six demand equations that have a preponderance of correct signs and significant variables. Differences in price and income elasticities are found between sectors with the residential sector being more elastic.

"Derived Demand for Energy in Agriculture: Effects of Price, Substitution, and Technology." Edward K. Mensah and John A. Miranowski (Iowa State University)
The derived demand for energy and nonenergy inputs in U.S. agriculture is estimated based on a translog cost function. The estimated coefficients are used to derive own-price and cross-price elasticities of demand and Allen partial elasticities of substitution. The implications of these elasticity estimates for energy modeling are evaluated.

Commodity Demand and Prices (Clyde Greer, Montana State University, Chairperson)

"Univariate Residual Cross-Correlation Analysis: An Application to Beef Prices." Stephen E. Miller (Clemson University)
This paper provides a discussion of univariate residual cross-correlation analysis. This methodology allows an empirical assessment of lead-lag relationships between economic time series. For illustrative purposes the methodology was used to analyze lead-lag relationships between beef value changes at the retail, wholesale, and farm levels.

"Estimation of Income-Expenditure Relationships for Beef Using Spline Functions." Chung-Liang Huang and Robert Raunikar (University of Georgia)
Household expenditure data for ground beef, beef roasts, and steaks were fitted by spline functions. The results indicate that there is a unique expenditure pattern for each type of beef and there are sharp contrasts in marginal propensity to consume for specific types of beef among different household income levels.

"A Trend Projection of High Fructose Corn Sweetener Substitution for Sugar." Hoy F. Carman and Peter K. Thor (University of California-Davis)
High fructose corn syrup substitutes directly for sugar in many food processing applications. Its continued rapid acceptance has economic implications to sweetener industry participants and others. A nonlinear trend projection indicates that because of substitution, per capita and total U.S. sugar consumption likely will decrease during the next decade.

"U.S. Potato Demand: Static and Dynamic Characteristics." Edmund Estes, Leroy Blakeslee, and Ronald Mittelhammer (Washington State University)

Aggregate demand relationships for the U.S. potato industry are estimated by two-stage least squares. Demands were found to be price inelastic suggesting that abrupt changes in production cause major inverse price effects. Secular demand shifts are relatively rapid. Together these suggest opportunities for expanded production but a need for careful planning to avoid price depressing effects from even moderately excessive production growth.

"Demand and Prospects for Cocoa in the 1980s." Aja Okorie and David Blandford (Cornell University)
Estimated demand equations for the major consuming countries/blocs are used to project consumption and revenue in 1985 under alternative price/income scenarios. On the basis of recent production trends it is concluded that from the producers' perspective the prospects for cocoa in the 1980s look very promising.

International Trade (Cathy L. Jabara, ESCS, Chairperson)

"Trade Adjustment Assistance and Labor Displacement in the U.S. Sugar Industry." Lloyd Harbert and David Blandford (Cornell University)
If the price of sugar was reduced to the minimum under the International Sugar Agreement, wage payments to farm labor would be reduced by $39.7 million and to processor labor by $54.7 million. Only one-quarter of the 11,300 displaced processing workers would be eligible for compensation under the existing adjustment assistance program.

"Economic Effects of Selected Trade Restrictions on World Sugar Trade." Mark A. Edelman and Walter H. Gardiner (Purdue University)
A spatial equilibrium approach was employed to analyze the short-run consequences of selected trade restrictions of major importing and exporting countries on the world sugar market. International sugar trade is examined in terms of global welfare, volume, value of receipts, and payments price per unit, and trade flows.

"An Analysis of the Impact of Exchange Rate Changes Using Price Linkages." William H. Meyers, Elizabeth J. Gerber (ESCS), and Maury E. Bredahl (University of Missouri)
A partial equilibrium model is derived for the computation of exchange rate effects. The model incorporates foreign internal demand elasticities and price transmission elasticities which take account of price insulating policies. The appreciation of the Japanese yen relative to the dollar was analyzed for wheat, feed grains, and soybeans.

"A Comparison of the Current United States and Canadian Wheat Marketing Systems." David L. Watt, Donald O. Mitchell, and John Ross (Michigan State University)
The U.S. and Canadian wheat marketing systems are compared over the 1971–78 period. Quantities exported relative to wheat supplies available for export are examined using annual data. Monthly price data is also used to examine the price behavior of U.S. and Canadian wheat exports.

"A Monte Carlo Analysis of the Estimation of Export Demand." James K. Binkley and Lance McKinzie (Purdue University)
A simple two-country trading model was used to compare three methods of estimating export demand: OLS, TSLS, and TSLS applied to domestic curves from which were derived excess demand. Estimator performance depends primarily on relative error variances around excess supply and demand. The third method was generally superior.

Marketing, Temporal and Spatial Issues (Jon A. Brandt, Purdue University, Chairperson)

"Congestion in the Agricultural Marketing/Transportation System: A Case Study." Mechel Paggi and Stephen Fuller (Texas A&M University)
This paper focuses on the problem of congestion in the agricultural marketing transportation system. The purpose of this study is to (*a*) examine methodology for evaluating the cost of congestion, (*b*) relate appropriate research techniques for modeling traffic-congested systems, and (*c*) carry out analysis of congestion arising in the truck-to-ship intermodal grain transfer systems at the Port of Houston. A stochastic network simulation model was constructed to carry out the queuing analysis.

"Integrating Static Approaches to Location Problems into Dynamic Analyses." Virgilio A. P. Machado, Daniel S. Tilley, and Richard L. Kilmer (University of Florida)
A mixed-integer programming model with multiple products and economies of scale in processing is integrated with dynamic programming to allow dynamic analyses of plant location problems. The model is illustrated with an analysis of fresh citrus packing in Florida.

"A Multi-State Approach to Agricultural Issues: The Northwest Agricultural Development Project." James Youde, Robert McKusick, and Bruce Prenguber (Northwest Agricultural Development Project—Vancouver)
The project develops information on tradeoffs among development objectives and future resource and market requirements and constraints. Linear programming and input-output techniques are linked to analyze agricultural production and resource use by multicounty production areas and to estimate state income and employment impacts. The model considers numerous agricultural policy issues.

"Economic and Epidemiologic Policy Implications

from the National Brucellosis Technical Commission Study." Stephen H. Amosson, Raymond A. Dietrich, and John A. Hopkin (Texas A&M University)
This paper analyzes policy implications arising from the National Brucellosis Technical Commission Study. A systems simulation model was designed to estimate physical losses resulting from alternative bovine brucellosis programs. Benefit-cost ratios were calculated by program alternatives for determining economic and epidemiologic implications.

"Temporal Implications of Limitations on Annual Irrigation Water Pumped from an Exhaustible Aquifer." Daniel C. Hardin (Texas Water Resources Institute) and Ronald D. Lacewell (Texas A&M University)
Economic waste caused by uncontrolled pumping of groundwater is of major concern on the Texas High Plains. A recursive linear programming model is used to evaluate various annual limitations of aquifer depletion. Choice of an optimal temporal allocation of groundwater depends greatly on the interest rate chosen for the analysis.

Natural Resources and Environment (Ivery Clifton, University of Georgia, Chairperson)

"Estimating a Potential Cropland Supply Function for the Mississippi Delta Region." Robert N. Shulstad, Billy E. Herrington, Ralph D. May, and E. Moye Rutledge (University of Arkansas)
A potential cropland supply function is constructed under conditions of alternative product prices, crop rotations, factor costs, management levels, and discount rates with special emphasis on the conversion costs of woodland and pastureland. The research will help provide a projection of regional resource use in U.S. agriculture and form the basis for projected expanded input use and the resulting environmental pressures of such expansion.

"Further Evidence on the Effectiveness of the California Land Conservation Act." Daniel J. Dudek and Richard E. Howitt (University of California-Davis)
The effectiveness of use-value assessment in maintaining open space and in deterring the conversion of prime agricultural land to urban uses is evaluated in the San Joaquin subbasin for the period 1958–74. Results indicate that the act is a significant policy variable exhibiting the intended effects upon idle and agricultural land stocks, but that it is ineffective in controlling the growth of urban stocks on prime land.

"Optimal Sequential Sampling of Natural Resource Stocks: An Application of Kalman Filtering." Bruce L. Dixon (University of Illinois) and Richard E. Howitt (University of California-Davis)
For sequential estimation of resource stocks, partial replacement sampling is conventionally thought to give stock estimates with lower standard errors than estimators using simple random samples. Viewing resource production scheduling as dynamic, stochastic optimization, partial replacement sampling is shown to be inefficient in certain instances compared with simple random sampling.

"Analysis of the Economic Impact of Water-Based Recreation in Eastern Oklahoma." James C. Chang and Daniel D. Badger (Oklahoma State University)
The McClellan-Kerr Arkansas River Navigation System provides many water-oriented recreation areas and facilities. The objective of this paper was to estimate the impact of water-based recreation on various industries in Oklahoma. Recreation on the navigation system will generate an additional output of goods and services of $115 million, 7,400 additional jobs, and $38 million in additional income for all input-output industries in Oklahoma.

"Integrated Pest Management in Corn Rootworm Control: An Economic Assessment." John A. Miranowski (Iowa State University)
Integrated pest management in corn production provides cultural and chemical strategies for corn rootworm control. Economics can aid in selecting the optimal management strategy. In selecting the optimal strategy, this study considers both expected net returns and risk. Under current price and cost conditions, cultural control strategies dominate.

Marketing Issues (Alden Manchester, ESCS, Chairperson)

"Quality Choice in a Product Market." John Spriggs (Purdue University)
The paper presents a simple method for measuring the welfare loss from a suboptimal quality choice. The measure of welfare loss may help determine whether moving to the optimal quality choice is worthwhile. By way of illustration the method is supplied to the corn export market.

"The Influence of Alternate Pricing Methods on Ex-Vessel Shrimp Prices." John P. Nichols and Larry Johnston (Texas A&M University)
The relationship between ex-vessel pricing methods and interport price differentials for shrimp was examined. Ex-vessel prices were found to be significantly higher in ports using a pack-out method of establishing the value of landed shrimp when compared to box-weight ports. This differential was shown to vary by seasons and in direct relationship to the weekly change in prices in pack-out ports.

"Revisiting the Advertising-Concentration Issue." Ronald W. Ward and Robert M. Behr (University of Florida)
Advertising intensity is shown to be positively related to SIC four-digit measure of concentration. Advertising within the consumer nondurable industries is particularly influenced by increased concen-

tration. Likewise, the advertising-concentration relationship has intensified over time, suggesting an increase in nonprice competition especially for the food and related industries.

"An Imperfectly Competitive Market Model of the U.S. Lettuce Industry." Michael D. Hammig and Ron Mittelhammer (ESCS)
A simple econometric model of the U.S. lettuce industry is constructed based on an imperfectly competitive market structure with uncertain profit outcomes at the grower level. The model is simulated to provide insight with respect to impacts on the industry of higher wages for hired farm labor.

"Vertical Coordination through Spot Market Contracting and Integration." Richard L. Kilmer and Ronald W. Ward (University of Florida)
Economists have assumed the spot market is a most efficient allocating mechanism. The welfare differences resulting from transactions costs from a spot market, contract or vertical integration, are explored. As increased control over supply is achieved, a tradeoff emerges between increased utility from increased demand and decreased utility from higher costs. The resulting differences in welfare from using each alternative market are shown.

Farm Management Extension (Garnett L. Bradford, University of Kentucky, Chairperson)

"Impacts of a Computerized Management Decision Making Model on Farmers." Charles L. Moore, Sr., David L. Debertin, Larry D. Jones, and Angelos Pagoulatos (University of Kentucky)
This paper examines the impacts of a computerized decision making model on farmers' decisions. A questionnaire completed at the conclusion of the workshop measured farmers' intentions. A follow-up survey one year later assessed the extent to which these intentions were realized.

"The Implications of the FACTS System for Farm Management Extension and Research." Ed Carson (Purdue University)
The FACTS system is an interconnected system of "smart" computer terminals linking the counties of Indiana and the agricultural departments at Purdue University with each other. The system is expected to multiply the farm management extension program significantly. The system must perform well and gain agent and farmer acceptance and staff support.

"Use of the Programmable Calculator in Agricultural Economics Extension." James M. McGrann (Texas A&M University) and William M. Edwards (Iowa State University)
The programmable calculator is a recent addition to the set of tools available for aiding extension professionals, farmers, and agribusiness firms in management decision making. Multidisciplinary programs have been developed and distributed through a subscription library. The programmable calculator is valuable for extension workers in preparation of materials, instruction during meetings, and direct farmer assistance.

"Swine Farm Simulation: An Effective Extension Model." Allan E. Lines (Ohio State University)
The paper presents a unique model that simulates present, selected, and near optimal growth and organization strategies for the swine farm over a five-year planning horizon. Decisions made by the user on the model include product size, growth, management system, scheduling, and building type.

"An Evaluation of Southern Cooperative Extension Programs Aimed at Small and Part-Time Farmers." David Orden and Steven T. Buccola (Virginia Polytechnic Institute and State University)
Results of a model developed to explain farm sales changes of participants in southern extension small-farm programs indicate that sales revenue increases are affected by the initial level of farmers' resources, the extent of their program participation, characteristics and training of the field staff, and output price changes and environmental effects on yields. Policy implications are considered.

Futures, Hedging, and Pricing (James A. Niles, University of Santa Clara, Chairperson)

"Futures Prices of Beef Cattle and the Theory of Nonstorable Commodities." Steve Blank (University of Hawaii)
The long held hypothesis of independence between futures prices of individual delivery month contracts for nonstorable commodities is tested for live cattle and feeder cattle. The hypothesis is rejected for both sets of data. It is also suggested that the volume of trading, composition of trading activity, and characteristics of traders in a market will influence prices generated by that market.

"The Potential for Using Midwest Futures Contracts to Reduce Risk and Increase Storage Returns on Pacific Northwest Wheat." Joe Dewbre and Leroy Blakeslee (Washington State University)
Procedures are developed for forecasting weekly cash prices for white wheat and the basis separating white wheat prices and Midwest futures prices. Forecast variances of each are supplied. A procedure is developed for choosing from among marketing options having uncertain outcomes. Operating results are simulated for the 1972/73–1977/78 storage seasons.

"Incorporation of a Price Forecasting Equation into Selective Hedging Strategies for Corn." David E. Kenyon and Craig D. Cooper (Virginia Polytechnic Institute and State University)
December futures prices during the growing season for corn were predicted as a function of estimated

ending stocks and production. Predicted futures prices were incorporated into hedging strategies. Strategies using predicted futures prices were superior to routine hedging, but not superior to strategies using technical price indicators.

"Market Equilibrium with Random Production." Bruce Gardner and Jean-Paul Chavas (Texas A&M University)
The conditions for competitive equilibrium in a market with random production are examined. It is found that a mean-preserving increase in yield variability changes the competitive equilibrium output even when producers are risk-neutral. This fact creates problems for a common specification of equilibrium in the price stabilization literature.

"Price Disequilibrium Versus Price Equilibrium: A Question of Modeling Approaches." Harry S. Baumes, Jr. and Abner W. Womack (ESCS)
Price equilibrium and price disequilibrium are two modeling approaches that have been used to represent the underlying economic and/or operational structure for agricultural commodity models, particularly field crops. This paper compares both of these model structures as applied to the U.S. corn industry and discusses the implications of each.

Marketing Cooperatives and Cartels (Anne E. Peck, Stanford University, Chairperson)

"Wheat Cartelization in the Presence of a Market Intermediary." Colin Carter and Nancy Gallini (University of California-Berkeley)
This paper examines a von Stackelberg behavior of an intermediary firm in the wheat market. It demonstrates that the intermediary acting as a leader in the market will oppose the formation of a wheat cartel. Although the marketing charge does not change with the introduction of the cartel, volume traded decreases thus decreasing total revenue to the intermediary firm.

"International Trade, Cartels, Customs Unions, and Centrally Planned Economies." Robert G. Chambers (Ohio State University)
A simple 2×2 model of international trade is used to demonstrate that an international cartel or customs union, with monopoly power in trade, may prefer autarky to tariff-protected trade if a distortionary wage differential exists.

"Analysis of Factors Associated with Over-Order Prices in Federal Milk Orders." E. M. Babb, D. A. Bressler, and J. W. Pheasant (Purdue University)
Data on over-order pricing in U.S. federal milk orders are related to measures of cooperative and processor concentration, milk utilization, costs of alternative milk supply, and cost of production in a time-series cross-section regression analysis. The data suggest a strong relation between over-order price and costs of alternative supplies. No definite relation is found between the other variables.

"Existence, Correlates, and Perceptions of Selected Conduct Patterns in the Dairy Industry: Implications for Industrial Organization Research." Robert D. Boynton (Purdue University)
Industrial organization research has found the conduct variable elusive. This situation is nowhere more critical than in regulatory policy, specifically in the dairy industry. Primary data from dairy cooperatives and proprietary firms was used to measure the existence of and attitudes toward selected behaviors and explain their bases.

"Gibrat's Law and Growth of Agricultural Marketing Cooperatives." Robert A. Skinner and Thomas L. Sporleder (Texas A&M University)
Gibrat's Law is that growth rate and size are independent. Various empirical tests of the validity of Gibrat's Law for regional marketing cooperatives in the United States are presented. The empirical tests do not support Gibrat's Law and support the hypothesis of minimum efficient size among marketing cooperatives.

Farm Size and Organization (James K. Whittaker, Oregon State University, Chairperson)

"An Improved Procedure for Evaluating Alternative Farm Sizes." James W. Richardson and Gary D. Condra (Texas A&M University)
The methodology used in existing farm size studies fails to consider explicitly the following factors: time, risk, and uncertainty; alternative financial arrangements; income taxes; changing land prices; increasing input costs over time; and year-to-year net cash flows. A procedure that incorporates these factors is described in this paper and demonstrated by evaluating four alternative farm sizes.

"Some Evidence on Pecuniary Economies of Size for Farm Firms." Bernard V. Tew, Wesley N. Musser, and Bill R. Miller (University of Georgia)
This paper presents an empirical analysis of the assumption of constant variable input prices, which is generally made in studies of economies of size in farming. The empirical analysis supports this assumption even though some responsiveness of price to quantity of input was found.

"A Conceptual Model of the Stubble Replacement Decision for Florida Sugarcane Growers." Donald R. Crane, Jr. and Thomas H. Spreen (University of Florida)
Sugarcane is a perennial plant which grows back each year after harvest. A number of factors combine to cause yield to decline as the stubble ages. The stubble can be viewed as an asset with declining productivity. Asset replacement theory is reviewed and a series of three optimization models are proposed to quantify the replacement decision.

"Agronomics and Economics of Alternative Saginaw Valley Cropping Systems." Roy Black, Roger Hoskin, Larry Connor, Don Christenson, Zane Helsel,

Vern Meints, Fran Wolak, and Tom Burkhardt (Michigan State University)
Sixteen cropping sequences from Michigan's Saginaw Valley are ranked according to profitability. Crops include corn, soybeans, navy beans, wheat, sugar beets, and alfalfa. The evaluation is completed from a whole farm perspective, where yields reflect explicit consideration of synergistic relationships among crops. Also, sequence specific machinery complements are generated.

"Economics of Grafting as Adjustment to Wine Price Changes in California's San Joaquin Valley." Nick K. Dokoozlian and Carl L. Pherson (California State University-Fresno)
The comparison of discounted cash flows indicated that grafting white varietals to red varietal vineyards was superior to establishing new white varietal vineyards. Both options were superior to maintaining red varietal production under current price trends.

Food Policies and Programs (Paul A. Gessaman, University of Nebraska, Chairperson)

"The Impact of the Food Stamp Program on Household Food Purchases." Larry E. Salathe (USDA)
A theoretical model indicates the marginal impact of an increase in bonus on food purchases varies with household income. Previous studies have ignored this varying effect, probably resulting in inaccurate estimates. Existing survey data do not contain the information needed to measure more accurately the impact of the Food Stamp Program.

"Food Expenditures and the Food Stamp Program: Some Recent Evidence from the Consumer Expenditure Survey." Donald A. West (Washington State University)
Food expenditure patterns of households are examined using the BLS Consumer Expenditure Diary Survey data. Comparison of allocations of food-at-home expenditures among individual food items shows Food Stamp Program participants buy lower cost foods. Regression analysis indicates that income, home ownership, and food stamps directly affect food expenditures.

"The Nutritional Effectiveness of Three Federal Child Nutrition Programs: United States 1971–74." G. William Hoagland (U.S. Congressional Budget Office)
Data from the National Health and Nutrition Examination Survey (HANES) were analyzed to determine the nutritional effectiveness of three federal child nutrition programs. Breakfast program participants significantly improved their overall nutritional status relative to the control population. School lunch and school milk participants did not show a significant increase in their overall nutritional status.

"Economic Formula Pricing of Milk." Art Smith and Ronald D. Knutson (Texas A&M University)
Economic formulas have been proposed as a means of moving the minimum Class I prices in the Federal Milk Marketing Order system. Developed in this study is a theoretically sound procedure through which economic formulas can be determined that embody equilibrium conditions. Formula evaluation techniques, implementation, and policy implications are discussed.

"Distribution of Social Benefits with Optimal Control of U.S. Wheat Stocks." Won W. Koo and Oscar R. Burt (Montana State University)
A stochastic dynamic programming model was used to develop an economic decision rule on U.S. wheat exports and to evaluate distribution of social benefits. The U.S. wheat storage program gives most benefits to domestic producers, leaving domestic and foreign consumers worse off. An efficiency frontier curve is developed to show a trade-off between price stability and social benefits. It indicates that opportunity cost of price stability is larger than that of social benefits.

Environmental Quality (Stephen D. Reiling, University of Maine, Chairperson)

"Space and the Demand for Environmental Amenities." James Hite (Clemson University)
The amount of space over which an environmental amenity of a given quantity is available can serve as a measure of the quantity of that amenity for purposes of demand analysis. A simple paradigm incorporating that idea is developed and discussed.

"Economic Impact of Coastal Erosion on Shoreland Property and Structures." Waldon R. Kerns (Virginia Polytechnic Institute and State University)
Marginal values for tidal shoreline erosion induced losses to adjacent property and structure values were estimated by relating (*a*) historical erosion rates for individual parcels of property to value of that property and (*b*) changes in distance between structure and shoreline to value of those structures.

"A Low Cost Strategy for Reducing Agricultural Nonpoint Pollution in Lake Erie." D. Lynn Forster (Ohio State University)
A model is developed to simulate changes in net farm income in the Lake Erie Basin under alternative crop management practices. Results indicate that adoption of reduced tillage technologies on appropriate soil series causes little change in net farm income while nearly halving Basin soil loss.

"A Stochastic Methodology for Estimating the Value of Wetlands in Controlling Agricultural Nonpoint Pollution." William M. Park and Sandra S. Batie (Virginia Polytechnic Institute and State University)
Wetlands appear to buffer the effect on nonpoint pollution, smoothing out the time pattern of loading

to receiving waters. A stochastic methodology is required to value appropriately this function where high rates of pollutant loading in short periods of time pose a significant problem.

"Methodological Considerations in Estimating the Economic Value of Marsh and Estuarine Areas to Marine Production Processes." Gary D. Lynne and Patricia Conroy (University of Florida)
A methodology is developed and tested pertaining to a means to measure the economic value of these areas in the production of marketed marine species. The methodology draws heavily on the fish population dynamics modeling efforts. Declines in marsh acreage on Florida's Gulf Coast have caused declines in the marginal and average productivity of fishing effort in the blue crab fishery. The real impact, in a quantitative sense, however, has been small.

Community and Rural Development (C. Edwin Young, ESCS, Chairperson)

"Export Orientation of Nonmanufacturing Businesses in Nonmetropolitan Communities." Stephen M. Smith (University of Idaho)
Community characteristics—distance from nearest SMSA; size of local economic base—were most important in determining export orientation of nonmanufacturing businesses. Export level was also directly related to total firm expenditures, percentage of total spent nonlocally, and percentage of nonlocal ownership. Firm organization and business type were further distinguishing factors.

"The Effect of Intergovernmental Grants on Local Government Spending and Production Decisions: A Preliminary Econometric Model." John F. Savage and Bruce A. Weber (Oregon State University)
OLS regression results from a theoretically based model of county spending indicate that mental health (MH) grants stimulate MH spending. 3 SLS regression estimates of a simultaneous MH wage-labor-output model indicate that grants stimulate MH employment, wages are not endogenous, and production relationships need better specification.

"An Operational Extension of the Leontief Dynamic Input-Output Model." Thomas G. Johnson and Frederick W. Obermiller (Oregon State University)
Although conceptually superior to its static counterpart, the dynamic input-output model has failed to achieve popularity due to its virtual inoperability. Key extensions to the Leontief dynamic model facilitate specification using numerical and simulation techniques. The extended model's operability and capabilities are demonstrated using county-level data.

"Local Government Employment Trends: Some Perspectives on Growth and Tax Revolts." Leon B. Perkinson (ESCS, North Carolina State University)
Between 1957 and 1977, local government employment expanded rapidly relative to population but increased only slightly faster than real personal income. Since individual consumption of public services does not affect the individual's tax bill, decreasing consumption in response to falling real income does not directly reduce tax bills. This might lead to tax "revolts."

"Unemployment Insurance and Agricultural Labor Supply." Robert D. Emerson and Gustavo J. Arcia (University of Florida)
Long-run adjustments in labor supply resulting from the recent inclusion of farm workers under the Unemployment Insurance program are estimated in this paper. The adjustments to the revised work incentives are done on the basis of income and substitution effects evaluated from an estimated labor supply equation. The estimated adjustments are substantial, resulting in a 25% reduction in labor supply, *ceteris paribus*.

Inflation and Prices (Hal W. Everett, University of Illinois, Chairperson)

"Inflation Control through Commodity Supply Regulation." R. McFall Lamm, Jr. (ESCS)
The basic purpose of agricultural policy has been to redistribute income to producers and to stabilize farm prices. This paper suggests that agricultural policy also be used to control food price inflation. The results would be internal consistency between macroeconomic and agricultural policies and a decrease in total welfare loss.

"Inflation and U.S. Agriculture: A General Equilibrium Analysis of the Events of 1973." Shun-Yi Shei (Academia Sinica, Nankang, Taipei, Republic of China) and Robert L. Thompson (Purdue University)
An open general equilibrium econometric model of the U.S. economy, including a monetary sector, is used to decompose observed 1973 sectoral and aggregate price increases. In decreasing order the major causes found were U.S. monetary expansion, the Soviet grain deal, dollar devaluation, and the world crop failure.

"Macroeconomic Impacts of the 1979 Feed Grain Set-Aside Program." Joseph M. Roop (ESCS), Thomas M. Bell (University of Illinois), and Lloyd D. Teigen (Michigan State University)
The acreage response to the 1979 feed grain set-aside program is translated into prices and quantities for the major commodities via impact multipliers derived from USDA's Cross-Commodity Forecasting System. The prices and quantities are then translated into measures of agricultural aggregates such as cash receipts, farm income, and retail food prices.

"The Interrelationship of a Pesticide Regulation to Target Prices: A Multiple Policy Approach to Pest

Management." Reuben Weisz, Mike Lancaster, and Bill Quinby (ESCS)
Federal pesticide policies contradict and compliment other agricultural policies in ways that need to be explicitly recognized if a comprehensive evaluation of a pesticide policy is to be conducted. This paper presents a first attempt at this type of analysis.

"The Sensitivity of U.S. Wheat and Coarse Grain Exports and Prices to Alternative Yield Scenarios: A Forecast to 1981." Donald O. Mitchell and David R. Armstrong (Michigan State University)
The Michigan State University Agricultural Model is used to forecast U.S. wheat and coarse grain exports, prices, and stock levels for 1979, 1980, and 1981. Trend yield levels are assumed in the base simulation. The sensitivity of this assumption is examined by imposing yield decreases in the United States and Soviet Bloc.

Editor's note:
These Contributed Papers have been filed with University Microfilms. That firm will provide microfilm, microfiche, or hard copy for a small fee. Write Xerox University Microfilms, 300 North Zeeb Road, Ann Arbor, Michigan 48106.

Award-Winning Theses

Chavas, Jean-Paul. "A Quarterly Econometric Model of the U.S. Poultry and Egg Industry." Ph.D. thesis, University of Missouri, 1979.

The current world food problem and the recently experienced variability in domestic food prices have raised a number of forecasting and policy issues for the U.S. agricultural sector. One approach to the development of improved policies and forecasts involves an attempt to obtain better model representations of the agricultural sector. The present study addresses this problem by developing a model of the U.S. poultry and egg industry.

The industry-oriented objectives of the modeling exercise are to elucidate the various interrelationships that exist among major factors influencing the price determination in this subsector and to develop a quantitative procedure for generating forecasts. The more general objectives are to illustrate a modeling approach which would appear to have potential for improving the performance of large scale econometric models. The approach emphasizes the fact that the model is an approximation to the true economic system. The model specification is linear in the variables, allowing analytical investigation of its dynamic properties.

The production components of the model are structured to take advantage of technical information provided by industry specialists. As the model relies on quarterly observation, inventory fluctuations may have substantial impacts on price and consumption. The stocks equations are specified using specialized results obtained from a theoretical model emphasizing speculative and convenience motives for holding inventories. The consumption components of the model use price dependent mix-demand functions. Also, it was found that the wholesale price leads both farm and retail prices of eggs, broilers, and turkeys. For this reason, all the dynamic properties of the model rely on wholesale prices.

As the model is an approximation of a highly complex economic system, it is important to specify the model so that it can be revised continually to comply with information contained in most recent observations. For this purpose, the Kalman filter is used to update selected equations of the model. Results suggest that the Kalman filter is a potentially powerful tool for handling problems of structural change and updating in large-scale econometric models.

Mittelhammer, Ronald Carl. "The Estimation of Domestic Demand for Salad Vegetables Using A Priori Information." Ph.D. thesis, Washington State University, 1978.

The main objective of this dissertation is the econometric estimation of annual aggregate domestic demand schedules for fresh vegetables both at the retail level and at the derived farm level. A secondary objective is to examine the empirical behavior and assess the usefulness of a technique called mixed statistical estimation which allows the incorporation of linear probabilistic constraints on the parameters of an econometric model in the statistical estimation of the model.

The relations were estimated using sample information for the years 1954 through 1975 together with prior information derived from various sources including neoclassical demand theory, previous studies, and subjective beliefs.

The demands for the various salad vegetables were characterized by inelastic responses of quantities demanded to changes in vegetable prices both at the retail level and at the derived farm level. Many significant substitute and complementary relationships were identified between the various salad vegetables. The income elasticities of quantities demanded with respect to changes in disposable income were in the inelastic range at both the retail and derived farm levels. The total elasticities of price transmission representing the percentage changes in retail prices that occur due to percentage changes in farm values were all in the inelastic range.

The mixed estimation technique resulted in parameter estimates that were found to be more precise than estimates not using prior information. The estimated reductions in variances were substantial in the case of the retail demand equations, where the prior information was more precise than the sample information. The estimated reductions in variances were less substantial in the case of the margin relations, where the sample information was generally more precise than the prior information.

Sharp, Basil M. H. "The Economics of Managing Water Quality: A Multiobjective Analysis of Alternative Policies." Ph.D. thesis, University of Wisconsin, 1978.

In this thesis a methodology is developed for analyzing the economics of institutional alternatives designed to improve regional water quality. A multiperiod model was used to generate trade-offs between two noncommensurate objectives: water quality and net present value. The hierarchical structure of the model facilitated a synthesis of socioeconomic and ecological processes. In particular, the first level consisted of the following three submodels: a module that determines the level of dissolved oxygen; a pulp and paper firm

that represents a point source of pollution; and an agricultural firm that represents a nonpoint source of pollution. The institutional component of the model comprised the second level of the hierarchy and it was here that the firms' incentive structure was perturbed according to the specific abatement program invoked.

The model was used to illustrate the pivotal position that institutions occupy during the analysis, synthesis, and implementation of policy alternatives. Each pollution abatement program was made up of various combinations and levels of educational and technical assistance, cost sharing, low interest loans, and regulation. Ten alternative programs were analyzed with respect to their impact on the two criterion functions and their effect on distribution. The slope and the location of the trade-off surface, and the distribution of net present value and assimilative capacity was shown to be dependent upon the institutional arrangements used to implement policy. By recognizing the status quo, programs can be designed that are amenable to the specific economic entities involved, and at a minimum social cost.

AAEA Business

Committee Reports

Report of the President

It has been an honor and a privilege to serve as president of our Association. It has been a learning experience and a rare opportunity to become acquainted with a broad cross-section of our membership. There is a wonderful reservoir of good will toward the Association. The willingness of members to serve and assist in carrying out the work of AAEA is one of our important assets. In our efforts each year to document what has been done by the Board and the committee structure, how much we own, and how well we fared financially, we should not forget or neglect the good spirit and sense of responsibility which has been fostered among our members. Let me start this report by paying special tribute to our membership for expressing their opinions in all their diversity and for keeping their professional association vibrant and alive.

Our membership roll of individuals and library subscribers has numbered more than 6,000 for the past two years and should surpass that total again in 1979. Our membership committee, chaired by Gene Mathia is active. A new, blue brochure to solicit members has been developed by Bob Rauniker. All of us can assist by encouraging our colleagues and associates to participate in the Association through membership and volunteering to work on a committee or some activity.

There are at least three key ways a large number of members participate: (*a*) as members of Association committees, (*b*) as participants in the summer or winter meeting programs, and (*c*) as authors and reviewers of papers considered for publication in the *Journal*. My quick count indicates more than 250 members serve on AAEA committees currently with a little more than one-third of the members of these committees changing each year. I appointed more than 100 different individuals to committee assignments this year. They came from 49 states and a wide range of institutions and agencies. In addition, there are more than 300 people involved as chairmen, speakers, discussion leaders, and organizers for this year's summer meeting program. Editor Rhodes will shortly report receipt of over 300 manuscripts that were considered for publication and the involvement of almost 400 reviewers during the past year. Recognizing that there are some members who participated in more than one of these three categories, there are still enough joint authors to insure at least 1,000 different members have been involved in important ways in some aspect of AAEA activities this year. We can all take pride in this achievement and seek to insure that more of our members find ways to participate in the future.

One of the major accomplishments of 1978–79 was the publication of the *AAEA Newsletter*. The first four editions came out on schedule. Editor Rhodes has developed an interesting and readable sixteen-page format. Suggestions for content from the membership are encouraged. Jim Rhodes and his staff deserve our praise and thanks for making this new enterprise and service to members an instant success.

President Farrell appointed a special committee on management, structure, methods, and procedures in March 1977. Its chairman, W. Burt Sundquist, presented a final report to the Board in January 1979. One of its elements was a summary of a comprehensive survey concerning AAEA operations obtained from all officers and committee members who have served since 1970. This substantial effort was completed by a subcommittee chaired by Ludwig Eisgruber. In its final report the committee made the following points strongly reinforced by the survey:

(*a*) The effectiveness of AAEA operations has improved significantly in recent years, in part because specific responsibilities have been assigned to individual members of the Executive Board.

(*b*) The planning functions of the Board and the management of financial operations have been given high priority and are well received by members.

(*c*) Despite the lack of formal position descriptions and committee assignments, most office holders and committee members felt they had been given rather clear assignments and responsibilities.

(*d*) The need for strong and effective leadership by committee chairmen is recognized as the key to committee output and performance.

(*e*) There is a strong desire to keep policy decisions and Association activities retained in the hands of a broad base of Association members. Overall, the Sundquist committee found a positive response to the ways in which members have been involved in Association affairs.

The committee concluded its report, which will be published in the December *Journal*, with four major recommendations. Briefly, they are:

(*a*) the continuation and strengthening of the practice of assigning specific responsibilities to individual members of the Executive Board to design, monitor, and manage the activities of the Association;

(*b*) the establishment of a task force to develop operational position descriptions for the President-Elect, President, and Immediate Past President (a key objective is to spread their workloads more evenly over the years);

(*c*) the establishment of a small working task

force to consider and design an operational data base for use in management and programming activities of the Association;

(*d*) appointment of a task force to plan the establishment of an executive office for the Association to be operational no later than 1983 and to be located in either Washington, D.C., or Chicago.

The Board accepted the first three recommendations at its January 1979 meeting and task forces on position descriptions for the office of president and the development of an operational data base for the Association were appointed, chaired, respectively, by former presidents Jim Hildreth and Ken Farrell. The Board is proceeding more slowly on the fourth recommendation. An ad hoc committee chaired by John Stovall is collecting additional information on expected costs and benefits that might be associated with establishing an executive office for the Association and other alternative ways of carrying out the management functions of the Association. No action has been taken as yet on this recommendation. It is hoped that a limited set of alternatives will be budgeted and available for review at the December 1979 meeting of the Board. The membership will be involved in any major decision on the location and operation of our Association's office.

Much of the work of the Association is done through individual enterprises managed in part by Association committees. Good work is too often taken for granted. When things go well it takes very little of the Board's time. Members are apt to assume it all happens naturally.

The *Journal* is generally viewed as the Association's most important activity. We have been well served by our editors, past and present. The quality of the publication must be a reflection of what our members write as well as the decisions of the editors and their reviewers. Editors Rhodes, Johnson, and Stoevener have maintained high standards and a diverse, readable publication.

The Registry of Agricultural Economics is now an established enterprise operated under a memorandum of agreement with the Illinois State Employment Service. The credit for the overall success of this enterprise goes to many people. Particular mention should go to Loys Mather and Steve Harsh who have worked with this project from its inception. All of us should be sure that our names are included in the Registry. We should encourage students to use this service. Allen Johnson serves as chairman of Professional Registries and Employment Committee.

The Literature Retrieval Committee supervises the work of a joint enterprise between ESCS and AAEA, the American Agricultural Economics Documentation Center. It is located on the first floor of the building where ESCS is housed in Washington, D.C. AAEA's contribution of $17,000 a year covers about 30% of the cash costs of operating the Center. The computerized search system works well. If you have not used it you should. Someone at every location where agricultural economics literature is produced should be designated to send periodically publications to the Documentation Center. That will insure that important publications are reviewed and cited in the AGRICOLA system. If you are not familiar with the system visit Cynthia Kenyon's demonstration while you are here and discover first hand how the system works.

One of the important association activities each year culminates in the annual awards program. It involves many people both in the preparation and documentation of the nominating materials, and then the selection process itself. This program seeks to recognize excellence. One of its important components is the nomination process, which provides initial recognition for individuals and their work in their own organizations. The selection process necessarily is subjective, but good work is identified and we express our continuing thanks to the many involved, including the general awards chairman, Dan Padberg.

The annual meeting program is another major enterprise of the Association. For the past two years the Board has served as a program committee spending one full day in the fall concentrating on program topics, format, and establishing the invited paper sessions. President-elect King and I served as the selection committee to choose the organized symposia from among those proposed. The contributed paper sessions were established by a committee of seventeen members co-chaired by Lee Schrader and T. Kelley White. The papers for the twenty sessions at this meeting were selected from the 213 papers offered for review. The work of this committee deserves special commendation.

The International Committee has been particularly active in carrying out an AID-funded project, "Needs and Strategies for Improving Training of Agricultural Economists for Work in International Agricultural Development." This is a follow-up to a study conducted five years earlier by AAEA's International Committee. Darrell Fienup has taken major responsibility for the conduct of the study with the active assistance of a number of committee members. Preliminary results were discussed in a workshop in June at Michigan State University. Results will be discussed here in an organized symposium to be conducted by committee chairman, Harold Riley, and at IAAE in Canada in September.

Any brief review of Association activities during the span of a year is sure to leave out some of the important happenings. At least half of the active committees have gone unmentioned but their work is appreciated. We are especially indebted to the ad hoc committee chaired by Larry Connor which organized and conducted the member survey on whether or not AAEA should join CAST. The work of the Finance Committee is especially important both to the Board and the Association. Their continuing hard work is reflected in the results you see in our operating statement, balance sheet, and budget. John Redman's careful work is reflected in

these statements. Collectively they have served all of us very well.

In closing, I would like to pay special tribute to the outlook and atmosphere created by the Presidents of the Association during my years on the Board. Jim Nielson, Jim Bonnen, Ken Farrell, and Jim Hildreth have provided an important legacy to all who follow them. They all sought to involve a broad spectrum of the membership in Association affairs. They sought to run an open program, to insure that our members' diversity was properly represented in committees, in programs, and in Association activities. One of the reasons most of us feel good about AAEA is because these men worked so effectively to create good will and develop both cooperation and intellectual interchange.

Best wishes to Dick Crowder and Sylvia Lane, who leave the Board after three years of excellent service. They sought to instil a sense of discipline combined with good humor in our meetings and they succeeded.

The continuing challenge for all of us in the Association is to foster creativity and maintain a spirit of good will while encouraging new ways to serve member needs and interests. That requires members to ask hard questions and propose new activities while keeping our current programs lively. I am sure you will find ways to do it.

B. F. Stanton, President

Resolution

Whereas the American Agricultural Economics Association depends for its success on the selfless contributions of individuals and institutions, and

Whereas Washington State University and individuals associated with it have graciously hosted the joint annual meeting of the American Agricultural Economics Association and the Western Agricultural Economics Association;

Therefore be it resolved that the American Agricultural Economics Association express its deep appreciation to President Glenn Terrell and Vice-president Wallis Beasley of Washington State University; Ralph Loomis, Conference Coordinator; LeRoy Rogers, Chairman of the Department of Agricultural Economics; chairpersons and members of local arrangements committees; and the faculty members and families of the Department of Agricultural Economics for their hospitality and hard work which made this annual meeting a rewarding professional and social experience.

Be it further resolved that a copy of this Resolution be sent to President Terrell, Vice-president Beasley, Professors Loomis and Rogers, to each of the local arrangements committees, and to other persons as appropriate.

Report of the Secretary-Treasurer

The AAEA membership for 1978 declined slightly from the all time high of 1977 (table 1). The decline would have been greater had it not been for the policy on charging a differential registration fee for the meeting at Virginia Polytechnic Institute and State University. The decisions to charge a differential registration fee, to invite only members to serve on committees and give papers at the annual meeting, to give discounts on books, to be listed in the *Handbook-Directory*, etc., have given a big boost to the membership effort and, consequently, to the financial well-being of the Association.

Table 1. Number of Members and Subscribers, 1978, with Comparisons

Category	1971	1972	1973	1974	1975	1976	1977	1978
Institutional members	34	25	20	22	25	26	36	32
Regular members								
U.S.	2,856	2,802	2,504	2,756	2,779	2,731	2,976	2,884
Foreign	486	601	487	480	503	766	809	811
Senior members[a]	0	0	0	0	0	47	98	137
Junior members								
U.S.	635	398	316	338	484	483	482	462
Foreign	53	38	161	68	66	49	41	47
Corresponding[b]								
U.S.	2	0	0	1	2	0	0	0
Foreign	100	82	184	198	207	0	0	0
Libraries and business								
U.S.	619	647	635	667	670	572	725	670
Foreign	1,111	1,196	1,168	1,242	1,227	1,164	1,245	1,271
Exchange	2	2	3	3	3	3	3	3
Total	5,898	5,791	5,478	5,775	5,966	5,841	6,415	6,317

[a] New category established in 1976.
[b] Category combined with regular members in 1976.

The number of members who paid their dues on or before 1 April 1979 and, therefore, received a ballot to vote increased by 291 (table 2). In addition to voting, it appears that members are paying more promptly.

The operating statement for Association business during 1978 showed a net gain of $88,895 (table 3). As I have in all previous reports, let me again caution everyone that in analyzing operating statements, extraordinary items often convey normal

Table 2. Number of Members Paid by 1 April; Ballots Mailed and Returned, with Comparisons

Category	1974	1975	1976	1977	1978	1979
U.S. members	2,401	2,746	2,878	2,721	2,756	2,955
Canadian members	178	156	175	170	157	154
Foreign members	248	592	443	452	440	535
Total ballots mailed	2,827	3,494	3,496	3,343	3,353	3,644
Total ballots returned	1,920	1,850	1,624	1,751	1,712	1,804

Table 3. 1978 AAEA Operating Statement, with Comparisons

Item	1974 Actual	1975 Actual	1976 Actual	1977 Actual	1978 Actual
			($)		
Income:					
Dues and subscriptions					
Regular members	53,723	55,545	87,952	98,894	100,103
Senior members	0	0	538	799	825
Junior members	2,608	4,295	8,294	7,705	8,117
Subscriptions	38,430	39,532	56,535	49,279	56,241
Corresponding	930	1,940	3,540	0	0
Institutional	2,200	2,500	2,600	3,600	3,200
Literature retrieval	5,262	3,283	0	0	0
Journal publications					
Journal sales	5,274	5,714	5,156	9,406	7,816
Page charges and reprints	4,452	9,575	26,700	31,294	36,023
Advertisements	820	825	1,375	328	1,196
Royalties	0	980	558	1,326	4,260
Other	0	0	0	0	0
Postwar Literature Review					
Sales	0	0	569	9,582	13,727
Investments	8,593	9,041	9,536	12,308	16,778
Annual meeting	4,193	270	710	1,369	2,000
Address labels	935	558	1,216	1,591	1,141
Miscellaneous	16,336[a]	464	223	427	2,643
San Diego	0	0	0	26,407	0
Gain (Loss) stock sale	0	0	0	0	21,121
Total	143,756	134,522	205,502	254,315	275,191
Expenses:					
Journal					
Printing	81,753	79,324	95,704[b]	88,733[c]	71,543[d]
Editorial support	23,400	17,700	20,000	30,000	22,500
Printing reprints	3,153	2,285	2,892	6,045	5,818
Purchase journals	569	324	165	147	98
Newsletter	0	0	0	0	670
Literature Retrieval Document Center	10,655	18,862	13,942	15,000	15,000
Postwar Literature Review	0	0	15,208	8,410	14,755
AAEA (Int. Conf.) Grant	0	0	5,000	0	0
Handbook-Directory	0	0	2,794	0	0
Awards	1,500	1,500	1,500	1,500	1,109
Student activities	1,130	0	0	0	0
General operations					
Postage and phone	2,962	3,880	4,466	4,611	4,141
Off. supp and printing	2,386	4,330	2,812	6,533	8,586
Annual meeting	4,461	1,713	1,271	2,814	5,251

Table 3. 1978 AAEA Operating Statement, with Comparisons (continued)

Item	1974 Actual	1975 Actual	1976 Actual	1977 Actual	1978 Actual
	($)				
Committees	357	460	1,211	1,041	488
Bonds	149	149	149	115	115
Audit	200	400	500	500	500
Secretary-Treasurer's assistant	13,874	14,001	15,728	20,750	17,338
Secretary-Treasurer honorarium	4,000	4,000	4,000	4,000	5,000
Miscellaneous	15,436[a]	850	810	792	13,384
San Diego	0	0	0	14,707	0
Total expenses	165,985	149,778	188,152	205,698	186,296
Balance	−22,229	−15,256	17,350	48,617	88,895

[a] Includes $15,000 Rockefeller Grant received and expended.
[b] For six issues of the *Journal*.
[c] For five issues of the *Journal* and *Handbook/Directory*.
[d] For four issues.

Table 4. USDL Operating Statement, 31 December 1978, with Comparisons

Item	1973	1974	1975	1976	1977	1978
	($)					
Beginning balance	0	25,100	7,434	8,844	−753	−15,003
Amount received	37,500	32,000	49,500	22,000	15,000	0
Expenses	12,400	49,666	48,090	31,597	29,250	4,739
Ending balance	25,100	7,434	8,844	−753	−15,003	−19,742

activity. With this in mind, only about $50,000 can be thought of as a "normal" gain in comparison to previous years. Included in the $88,895 is a capital gain of $21,121 realized from the sale of 600 shares of stock in Clark Equipment and about $17,000 resulting from having paid for one fewer issues of the *Journal*. The royalty income tripled because of the $3,458 received from sales of the Literature Review. Subscription income increased by about $7,000, page charges by nearly $5,000, and investment income by about $4,470. The $2,000 annual meeting income was the payment of the $2,000 advance made for the annual meeting and is offset by $2,000 on the expense side. The miscellaneous income of $2,643 consisted of $43 in exchange allowances not offset by charges, a $100 gift, and a $2,500 grant from Kellogg Foundation for financing our Kellogg Lecture.

Expenses ran about as expected. We always watch and question every expenditure. Only four issues of the *Journal* (December 1977, February 1978, May 1978, and August 1978) were billed during the year. The bills for November 1978 and December 1978 issues were received and paid in 1979. The Literature Review expenses increased but were mostly offset by income. Office supplies and printing increased because the inventories had to be replenished. The annual meeting expense consisted of $3,000 in advances to Virginia Polytechnic Institute and State University and Washington State University. The miscellaneous item included $11,500 for our word processor, $500 for refunds already recorded as income, $1,087 for exchange charges, $46 for copyright fees, and $250 for dues for the statistics users group.

The cost of secretarial assistance came out better than I really anticipated. During the year, I had considerable secretarial problems which meant that at times I had three people and at times only one. This also meant that I had to do more of the routine work personally.

The National Registry project funded by a USDL grant increased the year end deficit to $19,742 as we received no additional payment during the year and spent $4,739 (table 4). However, we did receive $15,000 in 1979, and the balance will be forthcoming upon completion of the final report. When completed, this project should close with zero balance and any additional funding will be a part of the regular budget.

Table 5. Income-Expense Statement of Editor's Office, 1978

	($)
Income	
AAEA appropriation	22,500
Expenses	
Salaries and fringes of assistant editor and secretary	21,399
Postage and telephone	1,961
Supplies	381
Total Expenses	23,741
Balance	−1,241

Table 6. Combined Balance Sheet, 31 December 1978, with Comparisons

	1973	1974	1975	1976	1977	1978
Assets	($)					
Cash-bank	81,118	54,195	54,941	12,321	47,362	12,969
Cash bank (USDL)	25,100	7,434	8,844	0	0	0
Cash-UK	(136)	291	1,714	3,510	4,983	6,741
Cash-broker	2,123	1,897	10,937	1,547	4,206	4,651
Prepaid expenses	0	8,850	0	0	0	0
Investments						
Certificate of deposit	0	0	0	40,000	40,000	85,046
Ready assets	0	0	0	7,547	15,568	26,168
Stocks (at cost)	102,552	102,552	102,552	102,552	102,552	129,366
Bonds (at cost)	0	0	0	0	0	49,632
Approximate market value (stocks)	182,886	136,433	159,310	202,490	176,042	178,233
Approximate market value (bonds)	0	0	0	0	0	46,092
Total assets (at market value)	291,091	209,100	235,746	267,415	288,161	359,900
Total assets (at cost)	210,757	175,219	178,988	167,477	214,671	314,573
Liabilities						
USDL unspent funds	25,101	7,434	8,844	(753)	(15,003)	(19,742)
Prepaid dues	27,896	32,254	49,869	30,605	50,431	66,178
Accounts payable	30,116	30,116	30,116	30,116	23,117	23,116
Net worth (at cost)	127,644	105,415	90,159	107,509	156,126	245,021
Net worth (at market value)	207,979	139,296	146,917	207,447	229,616	290,348
Total liabilities (at market value)	291,091	209,100	235,746	267,415	288,161	359,900
Total liabilities	210,757	175,219	178,988	167,477	214,671	314,573

In accordance with the policy established in 1973, the income-expense statement for editorial support as provided by the Editor is incorporated as a part of this report (table 5). It showed a deficit of $1,241.

The balance sheet for AAEA showed again considerable improvement (table 6). Our assets are carried on the books at cost. However, in previous balance sheets I showed the market value of the assets at the end of the year, so one could calculate the net worth at market value if desired. This time at the request of the Finance Committee, I included such calculations in the table. One must be more careful now in selecting the addends to arrive at the total desired. One additional comment on the balance sheet is that we are getting increasing amounts of prepaid dues and subscriptions.

In summary, the Association continues to be healthy and active. Inflation will continue to be a problem for sometime to come but the increasing pressure to provide more and more service from my office is the most immediate problem.

John C. Redman, secretary-treasurer

Investment Report

The portfolio, which went through considerable change during 1978, produced an income of $16,778. All assets carried on the books at cost of $290,212 had a market value of $335,539 at the end of the year (table 1). However, a large part consisted of near cash amounting to $111,214. We sold Clark Equipment at a nice gain over cost and purchased additional shares in American Cyanamid and Borden (table 2). We added CIT Financial and Santa Fe Industries. Also, we entered the bond market (table 3). The Finance Committee felt that debt issues, because of high interest rates, should have an important place in the AAEA portfolio. Presently, we are using our broker's ready asset account heavily to earn a high rate of return on funds not invested or not needed for immediate bills.

The portfolio subcommittee, consisting of Mike Boehlje, John Brake, and myself, has been rather active in trying to manage the portfolio well. Much gratitude is due Mike for his contributions, as he remained on the committee an extra year.

John C. Redman

Table 1. AAEA Summary of Investments, Year Ending 31 December 1978

	Income ($)	Value ($)	
	1 Jan.– 31 Dec. 1978	Cost	Market
Stocks			
On hand 1 Jan. 1978		102,552	176,042
On hand 31 Dec. 1978		129,366	178,233
Dividends	11,846		
Bonds			
On hand 1 Jan. 1978		0	0
On hand 31 Dec. 1978		49,632	46,092
Interest	1,937		
Miscellaneous[a]			
Ready asset trust 31 Dec. 1978	779	26,168	26,168
Certificate of deposit 31 Dec. 1978	2,216	85,046	85,046
Total (31 Dec.)	16,778	290,212	335,539

[a] Amount fluctuates.

Table 2. AAEA Stocks, 31 December 1978

				Market Value ($)		
Company	Number of Shares	Original Cost ($)	Dividends 1978 ($)	31 Dec. 1976	31 Dec. 1977	31 Dec. 1978
American Cyanamid	500[a]	15,073	656	6,969	6,688	12,688
Amer. Tel. & Tel.	288	11,421	1,296	18,288	17,424	17,424
Amer. Tel. & Tel. $4CV	300	16,934	1,200	19,950	19,013	19,050
Borden	300[b]	4,309	476	7,752	6,983	7,650
CIT Financial	300[c]	10,640	360	0	0	9,412
Chase Manhattan	93	1,115	205	2,848	2,778	2,732
Clark Equipment	0[d]	0	840	25,425	20,100	0
Con. Edison	232	7,467	557	7,337	6,699	5,974
Cont. Group	225	4,315	495	7,622	7,650	6,075
Exxon	306	10,325	1,010	16,409	14,726	15,032
Goodyear	500	16,693	650	11,875	8,625	8,062
Jewell	150	3,876	205	3,581	2,962	3,019
NICOR $1.90CV	7	0	13	208	220	182
Santa Fe Ind.	300[e]	10,299	495	0	0	8,850
Sears Roebuck	608	1,845	748	20,976	17,024	12,008
Std. Oil Ind.	800	7,357	2,240	47,700	39,600	45,300
Texaco	200	7,697	400	5,550	5,550	4,775
Total		129,366	11,846	202,490	176,042	178,233

[a] Purchased 250 shares @ $23.25 + $117.50 = $5,930.00 on 3-13-78.
[b] Purchased 72 shares @ $29.125 + $9.68 = $2,146.68 on 3-08-78.
[c] Purchased 300 shares @ $34.875 + $177.00 = $10,639.50 on 5-22-78.
[d] Sold 600 shares @ $39.50 − $348.00 = $23,321.21 on 8-31-78 (cost $2,200.67).
[e] Purchased 300 shares @ $33.75 + $174.00 = $10,299.00 on 3-07-78.

Table 3. AAEA Bonds, 31 December 1978

			Market Value ($)	
Bond	Original Cost ($)	Interest ($) 1978	31 Dec. 1977	31 Dec. 1978
CIT Financial 7⅝% 81 RG[a]	19,629	763	0	18,400
Comm. Credit Corp. 8⅞% 86 RG[b]	10,165	444	0	9,192
Federal Land Bank 7.3% 82[c]	19,838	730	0	18,500
Total	49,632	1,937	0	46,092

[a] Purchased 20,000 @ $96 + $428.61 = $19,628.61 on 8-23-78.
[b] Purchased 10,000 @ $101.5 + $14.79 = $10,164.79 on 3-07-78.
[c] Purchased 10,000 @ $96.5 + $251.44 = $9,901.44 on 8-24-78; purchased 10,000 @ $96.875 + $249.42 = $9,936.92 on 8-23-78.

Report of Tellers Committee

Ballots received from the secretary-treasurer of the AAEA were counted in accordance with the bylaws of the Association to preserve secrecy. Candidates receiving the largest number of votes were: Luther Tweeten for President-elect, Neil E. Harl and Carleton C. Dennis for directors.

Lynn W. Robbins
Joe T. Davis

Report of the Editor

A total of 307 new manuscripts were submitted 1978–79, compared to 269 the previous year. We accepted 33 articles and 61 notes, making an acceptance rate of 31%. These numbers are consistent with those of the 1970s. We expect to publish 55 Proceedings papers.

The average elapsed time between submission and publication of the articles published last year was 12.3 months. The publication process requires about four months; the remainder of the time is spent in review, author revision, and (occasionally) in a short queue prior to publication.

We have assisted in the renegotiation of the three-year printing contract and in committee deliberations concerning the new copyright law.

The Proceedings of the Economic Research Conference on U.S. Food System Regulation are being published as Part II of the November *Journal*. The editorial work and the publication costs are being provided by the Economics, Statistics, and Cooperatives Service of the USDA. Mrs. Victoria Smith and Dr. William Boehm are the special editors for that Proceedings.

Our newest venture, the *AAEA Newsletter*, has gone smoothly. We are disappointed that members have failed to take advantage of the "Viewpoints" section. We assume that use of the employment and bulletin board sections will increase as members' familiarity with them grows. AAEA committees can learn to use this communication avenue with the profession. We solicit suggestions for improvements.

We are pleased to acknowledge the extremely important assistance of many reviewers (listed below).

I would like to thank my associates for their hard work so essential to this enterprise. Stan Johnson as Associate Editor makes an immense contribution to the *Journal*. Herb Stoevener, as Book Review Editor, puts many hours into the Book Reviews. Marti Luzader, assistant editor, and Donna Taylor, secretary and recordkeeper, do all the detail work so necessary to publishing both the *Journal* and the *Newsletter*. By their efforts many authors have been rescued from convoluted sentences, dangling modifiers, and split infinitives. The people at Heffernan Press have performed their tasks efficiently and punctually. Finally, we thank the editorial council (inside front cover) for their efforts and support.

V. James Rhodes, editor

Reviewers, 1979–80

John C. Abbott
Philip C. Abbott
Irma Adelman
David J. Allee
Jock R. Anderson
Robert N. Anderson
Ahmed A. Araji
Richard J. Arnould
Arnold J. Aspelin
Emil D. Attanasi
Harry W. Ayer
Emerson M. Babb
Daniel E. Badger
Chester B. Baker
Timothy G. Baker
Malcolm D. Bale
Pranab K. Bardhan
B. Bruce Bare
John L. Baritelle
Randolph Barker
Peter J. Barry
J. M. Bates
C. Phillip Baumel
John A. Beath
Frederick W. Bell
Filmore E. Bender
Raymond R. Beneke
Charles H. Berry
Arlo W. Bieri
Hans P. Binswanger
Larry L. Bitney
J. Roy Black
Malcolm Blackie
Martin J. Blake
Leo V. Blakley
Melvin G. Blase
Allen Bock
Nancy Bockstael
Michael D. Boehlje
William T. Boehm
Robert W. Bohall
Richard N. Boisvert
Ray D. Bollman
Michael Bowes
Garnett L. Bradford
Michael G. Bradley
John R. Brake
George E. Brandow
Robert E. Branson
Maury E. Bredahl
Harold F. Breimyer
Ray F. Brokken
Daniel W. Bromley
William G. Brown
J. Bruce Bullock
Arvin R. Bunker
Oscar R. Burt
Boyd M. Buxton
Derek Byerlee
Gerald R. Campbell
Wilfred V. Candler
Thomas A. Carlin
Hoy F. Carman
George L. Casler
Emery N. Castle
Richard E. Caves
Robert G. Chambers
Jean-Paul Chavas
C. T. K. Ching
Parimal Choudhury
Marion Clawson
Willard W. Cochrane
Dale K. Colyer
Richard J. Crom
Pierre Crosson
Richard T. Crowder
Ronald G. Cummings
Dana G. Dalrymple
Rachel Dardis
Lee M. Day
Richard H. Day
Brady J. Deaton
Alain F. de Janvry
Allan C. DeSerpa
John L. Dillon
Joel B. Dirlam
William D. Dobson
Gerald A. Doeksen
Otto C. Doering III
John P. Doll
J. Kamal Dow
Marvin Duncan
Dan Dvoskin
Susan Early
Jerry B. Eckert
B. R. Eddleman
Vernon R. Eidman
Ludwig M. Eisgruber
David E. Ervin
Don E. Ethridge
Robert Evenson
Kenneth Farrell
Paul L. Farris
Jerry A. Fedeler
Loyd K. Fischer
Anthony C. Fisher
Thomas Fomby
D. Lynn Forster
John W. Freebairn
Ben C. French
J. E. Fruin
Earl I. Fuller
Stephen W. Fuller
William H. Furtan
Mason Gaffney
Bruce L. Gardner
Leon Garoyan
Gordon T. Gemmill
John O. Gerald
John Geweke
Roger W. Gray
Richard Green
Richard A. Greenhalgh
Thomas Grennes
Zvi Griliches
Russell L. Gum
Thomas F. Hady
Harold G. Halcrow
Darwin C. Hall
Harry H. Hall
Milton C. Hallberg
Albert N. Halter
Jerome W. Hammond
Charles R. Handy
Ian W. Hardie
Lowell S. Hardin
Neil E. Harl
Ancel D. Haroldsen
Zuhair A. Hassan
James B. Hassler
Joseph Havlicek
Murray H. Hawkins
Yujiro Hayami
Peter Hazell
Earl O. Heady
Dale M. Heien
Richard G. Heifner
Peter G. Helmberger
Dennis Henderson
Ralph E. Hepp
Robert W. Herdt
L. Dean Hiebert
Peter E. Hildebrand
R. J. Hildreth
Lowell D. Hill
R. Carter Hill
Irving J. Hoch
James P. Houck
Verne W. House
Wallace E. Huffman
Robert F. Hutton
Loren A. Ihnen
John E. Ikerd
P. C. Ip
Pauline Ippolito
George D. Irwin
Victor Jacobs
Lovell S. Jarvis
Glenn L. Johnson
Marc A. Johnson
Paul R. Johnson
Bruce F. Johnston
Timothy D. Josling
George Judge
Richard E. Just
Kandice Kahl
David Kamerschen
Ronald D. Kay
Earl W. Kehrberg
Maurice M. Kelso
Richard P. Kesler
John O. S. Kennedy
Mahmood H. Khan
Gordon A. King
Henry Kinnucan
Bill H. Kinsey
Yoav Kislev
Jack L. Knetsch
Ronald D. Knutson
Tetteh A. Kofi
Jose C. Kohout
Marvin W. Kottke
Kenneth R. Krause
Howard Kunreuther
John E. Kushman
Walter C. Labys
Ronald D. Lacewell
George W. Ladd
Sylvia Lane
Donald K. Larson
E. Phillip LeVeen
Raymond W. Leuthold
Robert K. Lindner
Harold G. Love
Edward A. Lutz
Ernst Lutz
Donald MacLaren
J. Patrick Madden
Wilbur R. Maki
Lester V. Manderscheid
J. S. Mann
Bruce W. Marion
Bert Mason
Robert Masson
Stephen F. Matthews
Scott C. Matulich
Leo V. Mayer
E. Scott Maynes
Alexander F. McCalla
Bruce A. McCarl
Kenneth E. McConnell
George R. McDowell
Andrew McGregor
James W. McKinsey, Jr.
Robert B. McKusick
John R. McNamara
W. W. McPherson
James D. McQuigg
Karl D. Meilke
John W. Mellor
Carmen Menezes
Stephen E. Miller
Thomas A. Miller
Robert A. Milligan
Ronald C. Mittelhammer
Jerry A. Moles
Larry C. Morgan
Bernard J. Morzuch
Timothy D. Mount
Willard F. Mueller
Yair Mundlak
Lester H. Myers
Darrel A. Nash
Walter Neely
Glenn L. Nelson
W. L. Nieuwoudt
James F. Nix
Thomas L. Nordblom
John A. Nordin
Gustavo Nores
Roger D. Norton
Virgil Norton
Andrew W. Novakovic
Carl W. O'Connor
Ronald A. Oliveira
James E. Osborn
D. K. Osborne
Donald D. Osburn
Enrique Ospina
Don Paarlberg
A. Parikh
Quirino Paris
Ernest C. Pasour, Jr.
Allen B. Paul
George Pavelis
Anne Peck
Richard K. Perrin
Gustof A. Peterson
Willis J. Peterson
Carl L. Pherson
Per Pinstrup-Andersen
Rulon D. Pope

Barry M. Popkin
David W. Price
Michael Proctor
Hans D. Radtke
Giles T. Rafsnider
Daryll Raitt
Alan J. Randall
Vadlamudi Y. Rao
Philip M. Raup
Gordon C. Rausser
Daryll E. Ray
Anthony J. Rayner
Barbara J. Redman
Shlomo Reutlinger
Joseph J. Richter
Donald J. Ricks
Kenneth L. Robinson
Richard N. Rosett
James A. Roumasset
Richard K. Rudel
William Ruesink
Vernon W. Ruttan
Mary E. Ryan
Alexander H. Sarris
Gerald E. Schluter
A. Allan Schmid
Stephen C. Schmidt
Andrew Schmitz
Roger E. Schneider
John A. Schnittker
David M. Schoonover
Lee F. Schrader
Ronald A. Schrimper
G. Edward Schuh
Alvin R. Schupp
John T. Scott
James D. Shaffer
J. Scott Shonkwiler
C. Richard Shumway
V. Kerry Smith
Heinz Spielmann
Thomas L. Sporleder
Thomas H. Spreen
John D. Spriggs
Bernard F. Stanton
William Staub
David W. Stevens
Russell Stevenson
Hans Stoll
N. H. Sturgess
Raymond J. Supalla
Richard E. Suttor
Earl R. Swanson
Takashi Takayama
Hovav Talpaz
C. Robert Taylor
Gary C. Taylor
Lloyd D. Teigen
Howard R. Thomas
Stanley R. Thompson
John F. Timmons
William G. Tomek
Randall E. Torgerson
William D. Toussaint
James N. Trapp
John Tressler
S. J. Turnovsky
Luther G. Tweeten
Fred H. Tyner
Edward W. Tyrchniewicz
Ronald Y. Uyeshiro
Peter van Blokland
John Vondruska
Arley D. Waldo
Rodney L. Walker
T. D. Wallace
Richard G. Walsh
T. K. Warley
Philip F. Warnken
Robert D. Weaver
Delane E. Welsch
Jerry G. West
Morris D. Whitaker
Fred C. White
T. Kelley White
Willard Williams
Elizabeth Wilman
Roger C. Woodworth
Pan A. Yotopoulos
Robert A. Young
Steven Zell
Anthony C. Zwart

Report of the Awards Committee

The winners of AAEA awards for 1979 are listed below.

Distinguished Extension Programs

Less than ten years. **J. Roy Black,** Michigan State University.
Ten or more years. **Wallace Barr,** Ohio State University.

Distinguished Policy Contributions

Howard E. Conklin, Cornell University.
G. Edward Schuh, Purdue University.

Distinguished Undergraduate Teaching

Less than ten years. **Paul D. Hummer,** Oklahoma State University.
Ten years or more. **Manning H. Becker,** Oregon State University.

Outstanding Doctoral Degree Program

Jean-Paul Chavas. "A Quarterly Econometric Model of the U.S. Poultry and Egg Industry." University of Missouri (adviser: Stanley R. Johnson).
Ronald Carl Mittelhammer. "The Estimation of Domestic Demand for Salad Vegetables Using A Priori Information." Washington State University (adviser: David W. Price).
Basil M. H. Sharp. "The Economics of Managing Water Quality: A Multiobjective Analysis of Alternative Policies." University of Wisconsin (adviser: Daniel W. Bromley).
Honorable mention. Peter George Bushnell. "Dynamic Analysis of the World Almond Market and the United States Almond Marketing Order." University of California, Davis (adviser: Alex F. McCalla).
Honorable mention. Leo da Rocha Ferreira. "Economics of Small and Sharecropper Farms under Risk in the Sertab of Northeastern Brazil." University of Florida (adviser: Woodrow W. McPherson).
Honorable mention. Michael Leroy Hardin. "A Simulation Model for Analyzing Farm Capital Investment Alternatives." Oklahoma State University (adviser: Odell L. Walker).

Outstanding Master's Degree Program

John Thomas Daubert. "Conjunctive Ground and Surface Water Allocations: The Economics of a Quasi-Market Solution." Colorado State University (adviser: Robert A. Young).
James Edward Davis, Jr. "The Theory and Measurement of Coupon Effectiveness: An Application of Error-Components Models." University of Florida (adviser: Ronald W. Ward).
Richard Eugene Haack. "An Analysis of the Economic Implications of Supply Management and Stabilization Programs in the Canadian Beef Sector." University of Guelph (adviser: Larry J. Martin).
Honorable mention. Gary L. Smith. "An Evaluation of the Impact of Improved Crop Information in the Market for Soybeans." Purdue University (adviser: Lee F. Schrader).

Quality of Research Discovery

Hans P. Binswanger, Vernon W. Ruttan, Uri Ben-Zion, Alain de Janvry, Robert E. Evenson, Yujiro Hayami, Terry L. Roe, John H. Sanders, William W. Wade, Adolf Weber, and **Patrick Young.** *In-*

duced Innovation, Technology, Institutions, and Development. Baltimore, Md.: Johns Hopkins University Press, 1978.

Ronald W. Ward and **James E. Davis**. "A Pooled Cross-Section Time-Series Model of Coupon Promotions." *Amer. J. Agr. Econ.* 60(1978):393–401.

Honorable mention. Ram D. Singh, G. Edward Schuh, and **Earl W. Kehrberg.** "Economic Analysis of Fertility Behavior and the Demand for Schooling among Poor Households in Rural Brazil." Purdue University Agr. Exp. Sta. Bull. 214, 1978.

Honorable mention. Earl O. Heady and **Roger Hexem.** *Water Production Functions for Irrigated Agriculture*. Ames: Center for Agricultural and Rural Development, Iowa State University Press, 1978.

Quality of Communication

Mary E. Ryan, Robert L. Tontz, Martin K. Christiansen, James P. Houck, Peter K. Pollak, Bob F. Jones, Robert L. Thompson, Jimmye S. Hillman, Anne E. Peck, Andrew Schmitz, Stephen C. Schmidt, Harold D. Guither, Arthur B. Mackie, Leo V. Mayer, and **Harold Breimyer.** "Speaking of Trade: Its Effect on Agriculture." University of Minnesota Agr. Ext. Serv. Spec. Rep. No. 72, November 1978.

Ron C. Allen, James Bauder, David W. Cobia, Gerhardt N. Fick, Basil Furgala, Harvey J. Hirning, Edna T. Holm, David H. Kinard, John D. Nalewaja, David M. Noetzel, William K. Pfeifer, Charlie E. Rogers, Leroy W. Schaffner, Robert and **Jay Schuler, Albert Schneiter, John T. Schulz, Tommy E. Thompson, David E. Zimmer,** and **Joseph C. Zubriski.** "Sunflower: Production and Marketing." North Dakota State University Ext. Bull. 25, July 1978.

Honorable mention. Charles Philip Gratto, Everett E. Peterson, James G. Kendrick, Otto Doering, Richard Barrows, and **Larry Libby.** "Perspectives on Tomorrow: Food-Population-Resources: The Issues and the Options." North Central Regional Pub. No. 53, February 1978.

Honorable mention. "Tar Heel Economist." North Carolina State University Agr. Ext. Serv., January–December 1978.

Publication of Enduring Quality

Marc Nerlove. "Distributed Lags and Demand Analysis." USDA Agr. Handbook No. 141, 1958.

Outstanding Journal Article

David Seckler and **Robert Young.** "Economic and Policy Implications of the 160-Acre Limitation in Federal Reclamation Law." *Amer. J. Agr. Econ.* 60(1978):575–88.

Daniel I. Padberg, chairman

Report of the AAEA Committee on Management, Structure, Methods, and Procedures

Our Committee was given an assignment by AAEA President Kenneth Farrell[1] with three principal objectives: (*a*) to review the management, structure, methods, and procedures of the Association and then to make recommendations to enhance the quality of service to members and the efficiency and operations of the Association; (*b*) to examine the feasibility of establishing an AAEA Executive Office for Program Management; and (*c*) to review the performance of the Secretary-Treasurer during the past three to five years. The latter review is in keeping with the operating procedures prescribed for the Executive Board of the Association at the Edmonton, Alberta, meetings in August 1973.

Consistent with our charge from President Farrell, we did not consider it the assignment of our committee to set priorities for activities in which the Association should be engaged, but rather to suggest procedures for improving the efficiency and management of the Association's operations. In addition to the inquiry and analysis conducted by individual committee members, a major survey of past officers and committee chairpersons of the Association was conducted under the leadership of Eisgruber. ("AAEA Survey on Management, Structure, Methods and Procedures," prepared by Ludwig M. Eisgruber, December 1978, 78 pages.)

Effectiveness of Current AAEA Operations

One perspective which came through rather clearly in response to the committee's inquiry (particularly from current and past Association officers) is that the effectiveness of AAEA operations has improved significantly in recent years. This improvement appears to be, at least in part, the result of assigning specific responsibilities to individual members of the Association's executive board. Particularly mentioned were improvements in the planning functions of the executive board and in the management of the Association's financial operations. Despite the almost complete absence of any "job descriptions" for officers of the Association, and to a major degree for committees of the Association, most Association office holders and committee members felt they had been given a rather clear charge in their assignment for the Association. As-

[1] Members appointed to this Committee on March 29, 1977, by then AAEA President Kenneth Farrell include: Wallace Barr, Richard Crowder, Ludwig Eisgruber, Olan Forker, Neil Harl, Leo Polopolus, John Stovall, and W. Burt Sundquist, Chairman. A more detailed Committee report was presented to the Executive Board of the AAEA in January 1979. That report included four detailed appendices relating to: (*a*) President Farrell's charge to the Committee and the procedures followed by the Committee in conducting its assignment, (*b*) a performance evaluation of the office of the Secretary-Treasurer, (*c*) a summary of the procedures and results from a major survey of past Association officers and committee chairpersons, and (*d*) evaluation of possible alternatives for an AAEA Executive Office.

sessment of the effectiveness with which these charges were implemented, however, varies considerably. The effectiveness of committee chairpersons in moving ahead with the committee's assignment appeared the most frequently mentioned of the key variables affecting committee performance. If the committee chairperson was well organized and aggressive, committee members were generally pleased with the ability of their committee to execute effectively their responsibilities. If the chairperson was not aggressive and effective, committee performance was less than satisfactory.

With respect to the adequacy of support provided to the Association's officers and committees, officers of the Association were generally satisfied with the financial support rendered to their activities by the Association while only a few members of committees felt that Association support was inadequate. The latter is probably not surprising, given the large number of Association committees in operation (33 in 1977).

Members of the Association appeared generally well pleased with the adequacy of membership representation on Association committees and on the executive board. Some dissatisfaction was expressed, however, relative to the adequacy of representation of "industry" members in the decision-making process and programming of the Association. Clearly, a large proportion of the Association membership is involved in Association activities including the planning and operations phases of those activities. Also, a major portion of the costs of managing and operating the Association is absorbed by the organizations and institutions who are employers of these Association members. During the period of tenure in office of the editor of the Association's *Journal,* the Association's secretary-treasurer, and the members of the Association's executive board (particularly the president), the employers of these office holders absorb heavy costs, particularly via subsidization of professional salaries.

Our inquiry indicated that much of the Association's viability is judged to rest upon an enthusiastic and active membership. Thus, a number of respondents indicated that their reaction to any change in Association organization and/or management rests importantly on the extent to which policy decisions and Association activities could still be retained in the hands of a broad base of Association members. Any significant increase in membership dues to finance an executive office for the Association was viewed with a good deal of disfavor by the majority of Association members surveyed.

Frequently mentioned by past and current Association officers was the judgment that effective operation and management of several Association activities (including membership recruitment and retention, professional employment, publication of *Handbook-Directory* materials, special professional training programs and workshops, appointments to committees and task forces, etc.) are highly dependent on an accessible up-to-date data base of Association members and new entrants to the profession together with at least some key informational items on individual members. Neither the current employment registry nor the current membership list kept by the office of the secretary-treasurer provides both the required accessibility and completeness of data base coverage. Moreover, this data base and other key information for decision making needs to be more effectively transferred than it currently is from retiring officers, Board members, and committee chairpersons to their replacements in these positions.

A final item of importance mentioned by several past presidents of the Association was that the workload currently assumed by the president of the Association during his (her) one-year term of office is excessive. The heavy workload of this office plus the current distribution of responsibilities on the executive board probably discourages and may even preclude adequate attention to important policy issues and innovative programming for the Association.

Evaluation of Secretary-Treasurer

The incumbent Association Secretary-Treasurer, Dr. John C. Redman, assumed his current office in the Association in January 1970. He has performed strongly and with a high degree of personal dedication. Clearly, the Secretary-Treasurer and his office staff have conscientiously carried a heavy workload for the Association with a high degree of cost effectiveness. Our recommendation to the executive board at the summer, 1978, Association meetings was (*a*) for renewal of an additional three-year term in office for the incumbent Secretary-Treasurer and (*b*) for an expression of appreciation for dedicated and high quality performance to the Secretary-Treasurer and his staff. In addition, we outlined several issues of the secretary-treasurer's office needing attention by the executive board. These relate to office equipment, staff benefits, needed liaison with other offices, development of more formalized position descriptions, and operating guidelines for the office.

Recommendations of the Committee

The Committee is cognizant of its advisory role. Thus, the four recommendations which follow are presented for consideration by the executive board of the Association. Further, we assume that any broad based changes in Association organization and structure, such as that outlined in the fourth recommendation (*d*), should have discussion by and approval of the Association's membership prior to implementation. With these caveats in place, and with knowledge that a task force is already working

on the development of operating guidelines for the office of the secretary-treasurer, we recommend the following:

(*a*) The continuation of and strengthening of the current practice of assigning specific responsibilities to individual members of the executive board of the Association to design, monitor, and manage the programmatic, financial, and administrative activities of the Association. Appropriate mechanisms for "accountability" should be developed and implemented for Board members and committee chairpersons.

(*b*) Immediate establishment of a task force consisting of the Association's immediate past president, and the president-elect, augmented by not more than two additional members to develop operational position descriptions for the Association's president-elect, president, and immediate past president. A key objective should be to outline a three-year sequence of responsibilities which spreads more evenly the workload of the Association's presidency and permits more effective attention to policy planning and to innovative programming. Such an allocation (or reallocation) of responsibilities may require the shifting of some part of the routine workload of program planning and management to other members of the executive board of the Association.

(*c*) Immediate establishment of a small working task force to specify an operational data base for use in management and programming activities of the Association and to plan for its operational implementation. We recommend that the Association's secretary-treasurer, membership committee chairman, and a representative of the employment registry be named as ex-officio members of this task force. Regular task force membership should include employer users of such a data base, a past president who has dealt with the committee selection task, and someone with operational computer capability. The task force should have an operational plan developed within a twelve-month period after appointment. This plan should be based on a thorough consideration of data needs for management and programming of the Association's activities and on the use of up-to-date data processing technology which insures ease of accessibility and effective maintenance of the data base. Recommendations (*a*) through (*c*) need to be put into effect and can be implemented by the executive board without deliberation by the general membership of the Association.

(*d*) Immediate appointment of a task force consisting of both current members of the Association's executive board and other Association members to plan the establishment of an executive office for the Association to be operational by no later than 1983 and to be located in either Washington, D.C., or Chicago.[2] At a minimum, this office should consolidate the current responsibilities and activities of the Association's secretary-treasurer with those of operation of a modernized data base for the Association's programming and management activities. Strong consideration should also be given to establishing effective linkages between this office and the employment related services sponsored by the Association. So as to maintain the broad policy and program-planning activities in the hands of Association members, we suggest the office be called "The Office of AAEA Program Support" and that the manager of this office be titled, "Director, Office of AAEA Program Support." Effective liaison should be established between this task force and the one specifying an operational data base.

In arriving at the fourth recommendation (*d*), we are cognizant of two somewhat conflicting interests. First, the vitality of our current Association is based heavily on the involvement in Association offices, committees, and general Association affairs of a large number of members who give generously, and with dedication, of their time and energies. We feel the need to retain this broad based interest and involvement of the membership and to avoid excessive increases in the cost of Association membership. On the other hand, we feel that some individuals and institutions must currently subsidize the Association's program and membership beyond reasonable and sustainable levels. And, certain dimensions of program planning and management probably can be upgraded only through a more centralized administrative operation. We believe that a centralized administrative office can be established to expand and improve services to Association members without prohibitive costs to individual members and with the retention of policy and program decisions by a broad base of Association members. But, the Association's membership should make the final judgment in choosing from well-defined alternatives.

Finally, we believe that transition to an executive administrative office for the Association within a time frame of 1981–83 will permit effective advance development of a computerized data base for programming and management of Association activities and a plan for consolidation of administrative services, and for phasing out existing staffing and phasing in the new staff.

W. Burt Sundquist, chairman

Report of the Ad Hoc Committee on AAEA Membership in CAST

The issue of AAEA membership in CAST has been a recurring one. In 1975, a committee consisting of

[2] This recommendation did not have the unanimous agreement of our Committee. We include it here, however, with the hope that it will provide the impetus for fleshing out a set of alternatives for effective future management of the Association's business operations.

Brandow, Castle, and Toussaint submitted a comprehensive report to the AAEA Board (*Amer. J. Agr. Econ.* 57(1975):1003–7). Their recommendation against joining CAST was accepted by the Board. The issue was again considered by an ad hoc committee consisting of Farrell and Schuh in 1978. The Board approved the recommendations that action be taken to discern from the membership whether or not it wished AAEA to join CAST. The President was directed to form a committee to develop a statement reviewing the advantages and disadvantages of joining CAST so that the members could make an informed decision.

In September 1978, President Stanton authorized an ad hoc committee to pursue this issue as "the committee deemed appropriate." The composition of the committee included AAEA members who had served on past CAST task forces, one who is on the board of directors of CAST, and another member who had had no association with CAST. The committee subsequently met to review previ-

Results of the AAEA Membership Survey on CAST

The results from the membership survey are shown in tables 1 through 4. Eight hundred and eighty-five members responded (a 20% response). More than half of the respondents were from universities, approximately one-fifth were from government, and the remainder were from industry, other occupations, or there was no categorization indicated. The results indicated that 50.4% of the respondents thought AAEA should not associate with CAST, 36.9% were in favor of association, 11.2% were undecided, and no response was indicated from 1.5% (table 1). Industrial and other occupational specialities indicated a majority as favoring associating with CAST, whereas university, government, and those who did not identify their employment category predominately were against associating (table 1). Graduate students were the only age experience category indicating a favorable response to AAEA membership in CAST (table 2).

Table 3. Rank Ordering of Reasons Cited for AAEA Joining CAST

Reasons Cited	Rank Ordering (1st or 2nd) 1	2	Not Cited
	------ (No.) ------		
A substantial number of agricultural professional societies are members of CAST.	6	13	165
A substantial number of agricultural economists have been and continue to be included on CAST task forces.	14	25	132
CAST provides an important vehicle for multidisciplinary interaction on policy issues.	169	80	18
CAST establishes a closer connection between agricultural sciences and current, public decision making.	93	120	44
CAST can respond to current policy issues more quickly than such groups as the National Academy of Sciences.	18	47	126
CAST has had an important impact on some policy issues.	6	15	183
Other.	13	2	299

Table 4. Rank Ordering of Reasons Cited for AAEA Not Joining CAST

Reasons Cited	Rank Ordering (1st or 2nd) 1	2	Not Cited
	------ (No.) ------		
AAEA should not be associated with possible implicit or explicit policy positions of CAST.	221	80	75
Industry financial support of CAST or participation on CAST task forces influences its objectivity.	55	96	184
The annual AAEA membership fee is excessive.	15	30	300
CAST membership may endanger AAEA's tax-exempt status.	8	23	304
CAST's operating procedures on task force authorization and composition, and press relationships are unsatisfactory.	37	61	248
CAST has had an insignificant impact on policy issues.	19	24	316
Other.	55	21	325

that they were still not sufficiently acquainted with CAST and its role and purposes, and 35.4% indicated that while they were sufficiently acquainted with CAST, they did not have strong feelings about AAEA membership in CAST.

Recommendations

The results of the survey indicate that a slight majority of the member respondents are opposed to joining CAST, and slightly more than a third of the member respondents are in favor of joining it. The results of the survey may be subjected to various interpretations. The committee made every effort to be objective and fair in preparing the questionnaire and materials for mailing. Nevertheless, the committee was criticized for "biasing" the survey against AAEA membership in CAST. The committee also was criticized for not being "hard enough" on CAST and explaining more of the controversies surrounding CAST. It is the judgment of the committee that the negative percentage indicated from the survey probably represents a lower bound inasmuch as CAST has come under increasing scrutiny since the mailing materials were prepared and approved by the AAEA Board in January 1979.

It is the recommendation of the committee, based on the results of the survey, that the American Agricultural Economics Association not become a society member of the Council for Agricultural Science and Technology. Currently, the President of the Association provides CAST, on request, a list of agricultural economists who might make a contribution to the efforts of a particular task force. Participation on the task force is at the discretion of the individual member. The committee recommends the continuation of this practice.

Larry J. Connor, chairman

Appendix

American Agricultural Economics Association Membership Survey—AAEA Membership in Council for Agricultural Science and Technology

1. At the cost of $1.00 per member, do you believe that the American Agricultural Economics Association should join the Council for Agricultural Science and Technology?
   ___ yes ___ no ___ undecided
   (Please check one)

2. If you checked "yes" in No. 1, please rank the following reasons (1 is most important, 2 next, etc. Rank as many as you consider important.)
   ___ a. A substantial number of agricultural professional societies are members of CAST.
   ___ b. A substantial number of agricultural economists have been and continue to be included on CAST task forces.
   ___ c. CAST provides an important vehicle for multidisciplinary interaction on policy issues.
   ___ d. CAST establishes a closer connection between agricultural sciences and current, public decision making.
   ___ e. CAST can respond to current policy issues more quickly than such groups as the National Academy of Sciences.
   ___ f. CAST has had an important impact on some policy issues.
   ___ g. Other (please specify) ________

3. If you checked "no" in No. 1, please rank the following reasons (1 is most important, 2 next, etc. Rank as many as you consider important.)
   ___ a. AAEA should not be associated with possible implicit or explicit policy positions of CAST.
   ___ b. Industry financial support of CAST or participation on CAST task forces influences its objectivity.
   ___ c. The annual AAEA membership fee is excessive.
   ___ d. CAST membership may endanger AAEA's tax-exempt status.
   ___ e. CAST's operating procedures on task force authorization and composition, and press relationships are unsatisfactory.
   ___ f. CAST has had an insignificant impact on policy issues.
   ___ g. Other (please specify) ________

4. if you checked "undecided" in No. 1, please check one of the following:
   ___ a. Still not sufficiently acquainted with CAST and its role or purposes.
   ___ b. Although sufficiently acquainted with CAST, do not have strong feelings about AAEA membership in CAST.

5. Please check the following:
   ___ a. Employer: Government ___ Industry ___ University ___
   ___ b. Professional status: Graduate Student ___ Professional < 40 years age ___ Professional ≥ 40 years age ___

Thank you for your cooperation.

Ad Hoc Committee on AAEA Joining COPAFS

In a letter to B. F. Stanton, 19 January 1979, Fred Leone of the American Statistical Association invited the AAEA to participate in a three-year pilot program to establish a "Committee of Professional Associations on Federal Statistics" (COPAFS). Acceptance of the invitation would involve AAEA designation of two members of COPAFS and a minimum contribution of $2,000 per year or $6,000 for the three-year pilot program. It also would involve the appointment of a committee on governmental statistics within AAEA (which could be a subcommittee of the Economic Statistics Committee).

President Stanton, in a letter of 5 February 1979, asked James Bonnen, Norman Coats, and Bruce Gardner to consider this issue and make a recommendation to the AAEA board.

To date (June 1979), eight associations have committed themselves to the pilot program. Six (including the American Economic Association) are contributing at the $2,000 per year minimum and two (American Statistical Association and American Sociological Association) at $3,000 per year. The pilot program would get its official go-ahead as of 31 December 1979, if funding is committed to put COPAFS near its $67,500 per year budget goal. The idea is to get about two-thirds of this from foundations, one-third from the associations. There is a commitment of a few thousand from Ford and $10,000 per year from Russell Sage, but there is still a distance to go on foundation funding—although the association funding is falling into place. (This information from Fred Leone.)

Considerations in Favor of Joining COPAFS

First, there are expected to be substantial changes in the federal data system and federal statistics in the next few years. AAEA members have a real interest in these changes—particularly in the collection and availability of good quality statistics of the most useful kinds pertaining to agriculture and to rural society. COPAFS may be influential in these changes. If AAEA is not involved, the changes have a reduced likelihood of serving rural data needs.

Second, the general decline in agriculture's political self-sufficiency leaves most rural institutions more dependent on urban society and political institutions. We no longer can rely on agricultural economists alone, or even the land grant univer-

sities or USDA as a sufficient political arm to promote the data base necessary for scientific progress in rural social science. COPAFS is a mechanism for agricultural economists to become part of a broader organizational base for improved statistics.

The preceding are the major reasons why COPAFS membership for AAEA would be beneficial to the agricultural economics profession. Some less central benefits are the following: (*a*) Regular contact of the AAEA representatives with professionals in other fields will be helpful in keeping up with events and interests of these groups in statistics. This knowledge could be useful in formulating our ideas and working for improvements in federal agricultural statistics outside COPAFS. (*b*) COPAFS is expected to contribute to the improvement of the federal statistical system, and AAEA support would contribute to the success of COPAFS. Therefore, we can expect our assistance to have some marginal effect on the overall quality of and investment in federal statistics. (*c*) AAEA would be, and would be perceived to be, a better citizen in the community of professional societies if we participated than if we did not.

Considerations Opposed to Joining COPAFS

There are two primary arguments in opposition to AAEA participation in COPAFS: (*a*) the cost $2,000 per year for three years; and (*b*) there is a chance, as in any such venture, that COPAFS could be ineffective or not fully represent AAEA interests. Thus COPAFS is a risky investment.

Two other issues have come up which we do not consider to be serious obstacles to AAEA participation in COPAFS but which have generated some concern.

First, the AAEA already participates in the Federal Statistics Users Conference (FSUC), and the question of overlap has arisen. In fact, the FSUC is one of the main supporters of COPAFS, and the two would work in cooperation. The difference is that FSUC represents general interests in federal statistics and is largely business-oriented. COPAFS is explicitly set up to be concerned with statistics as a basis for social science research. This is the topic that would seem to be of prime importance to AAEA in attempting to ensure the continued development (or prevent the further erosion) of the statistical basis for rural social science research.

Second, how the AAEA sees an outlay of time and money on COPAFS may be influenced by the outcome of the membership poll on CAST. However, the issues involving CAST are of a substantially different nature. CAST concerns public issues and taking positions on them. AAEA membership in CAST might promote better public choice, but such membership may not be of direct interest to agricultural economists themselves. COPAFS, on the other hand, involves issues of direct self-interest to the agricultural economics profession; therefore, even if the AAEA membership rejects CAST, participation in COPAFS should be given serious consideration.

Recommendation

We recommend that the AAEA join COPAFS for the period of the three-year pilot program, with careful annual review of its progress.

Bruce Gardner, chairman

Minutes

Minutes of the Executive Board Meeting, Pullman, Washington

The meeting of the Executive Board was called to order by President B. F. Stanton at 8:30 a.m., 28 July 1979.

Present: Voting Members:
Stanton, Lane, Coffey, Hopkins, Crowder, Hildreth, King, Brown, Schuh

Members ex-officio:
Redman, Rhodes, Eisgruber, Colyer, Blakley

Guests:
Tweeten, Harl, Rogers, Loomis

1. Stanton read the report of the Tellers Committee which indicated that Luther Tweeten was elected as president-elect and Neil Harl and Carleton Dennis were elected as directors.

2. Stanton reviewed the agenda and made additions.

3. Loomis as conference coordinator reported on local arrangements, indicating 770 economists had preregistered, 214 papers were scheduled, and plans were proceeding smoothly.

4. Redman presented the minutes of the January 1979 Board meeting. Lane moved the approval. Seconded. Passed.

5. Redman gave the report of the secretary-treasurer for 1978 and the report on investment activity for 1978. These will be presented at the general business session.

6. Coffey as chairman of the Finance Committee reported on the meeting held in Lexington, on 23 May. The report included a review of the 1978 operating statement and balance sheet, comparison of investment guidelines and performance, a proposed 1980 budget, and recommendations by the committee. Coffey moved that the deadline for payment of dues be moved from 1 April to 15 January and that membership shall become delinquent as of 16 January; if dues are not paid prior to that date, members will not be entitled to receive the February issue of the *Journal*. However, if dues are paid on or before 1 April, membership will be restored and the member will be entitled to vote. Back issues missed are to be supplied with an additional charge of $1.00 per issue to defray the cost of postage and handling. Seconded. Passed.

7. Coffey moved that the policy adopted at Blacksburg, Virginia, charging a $5.00 lump sum for mailing back issues of the *Journal* be rescinded and that $1.00 be charged for each issue mailed. Seconded. Passed.

8. Coffey moved that all dues and subscriptions be collected in U.S. dollars or its exchange equivalent. Seconded. Passed.

9. Coffey moved that members and nonmember subscribers of the *Journal* with addresses outside the U.S., Canada, and Mexico be assessed a surcharge of $2.00 to cover the postage differential for mailing the publication. Seconded. Passed.

10. Coffey moved that all present and future volumes of the *Literature Review* be handled and mailed direct by the University of Minnesota Press. Seconded. Passed.

11. Coffey moved that investment guidelines for the portfolio be updated and changed to read as follows:

(*a*) Choose a low risk portfolio with a buy and hold strategy;

(*b*) Achieve a minimum of 7.5% annual rate of return on market value;

(*c*) Achieve a 5% rate of growth in dividend payout.

(*d*) Hold a portfolio containing 15%–50% debt issues with remainder being in equity issues.

After considerable discussion of the adequacy of these guidelines, Coffey withdrew the motion. Crowder and Schuh agreed to develop a motion reflecting a consensus of the Board. Crowder moved the following guidelines for portfolio management:

(*a*) Maintain a diversified portfolio consisting of debt, equity, and cash or cash equivalent instruments;

(*b*) Encourage the Finance Committee to consider "nontraditional" debt issues, such as REIT's, mortgage funds, housing authority bonds, investment trust certificates, etc.;

(*c*) Achieve a moving two-year average rate of return at least equal to the rate of inflation (GNP);

(*d*) A buy and hold strategy shall be followed for debt and preferred stock issues;

(*e*) All recommendations to the Executive Board for common stock purchases will include a recommended stop-loss point. If the Executive Board approves the common stock recommendation, it will also approve or disapprove the stop-loss recommendation, including whether or not to place a stop-loss;

(*f*) Between Executive Board meetings, the Finance Committee is authorized to trade common stocks equal in value to a maximum of 15% of the value of common stocks in the portfolio. A stop-loss will be placed at a level not more than 15%

below purchase price levels of stock bought. The committee will report all stock transactions to the Board within one week of the transaction date. The committee will make a quarterly report to the Executive Board on the portfolio. Seconded. Passed.

12. Coffey moved that selected target prices be used in combination with selected stop losses on stock we wish to eliminate from the portfolio rather than a blanket stop loss on all stocks, and that the portfolio be monitored on a quarterly basis to select stock to be eliminated from the portfolio. Seconded. Passed.

13. Coffey indicated that the Finance Committee recommended approval of a revision of reprint charges and advertising rates in the newsletter, but that a decision on this matter be delayed until the editor's report is heard.

14. Coffey moved that the dues schedule and other revenue earning rates be set and expenditures controlled so that the portfolio at market value will be maintained in the rate of .75 to 1.5 times the annual expenditures. Seconded. After much discussion on the proposal the motion was defeated by a vote of 7–1.

15. Schuh moved that by-laws and Board policies be changed to reflect the above motions. Seconded. Passed. Harl agreed to propose these and other appropriate changes in by-laws for Board action near the end of the meeting.

16. Redman presented a supplemental report from the Portfolio Investment Subcommittee recommending the following points:

(*a*) No new investments should be made now and that funds remain invested in the Ready Asset account. The committee feels that equity markets still have not built a strong enough base for recovery and that the Ready Asset account will generate a yield comparable or better than current bond yields as well as being more liquid.

(*b*) Authority should be given to buy Continental Corporation at $23–24. The committee feels this is a quality issue and would like to purchase it should the price decline from its current level (26-1/2 as of 19 July).

(*c*) The portfolio should be moved from Merrill Lynch to Bache. Bache can provide similar services in terms of investing dividends and other liquid funds. Bache seems eager to service the account, is willing to provide an independent appraisal at their expense (in addition to their own), and appears to have more timely advisory services.

(*d*) The committee is reviewing the status of Chase Manhattan stock so that a decision can be made as to whether or not to eliminate it from the portfolio. Crowder moved the approval of moving the portfolio from Merrill Lynch to Bache. Seconded. Passed. It was felt that the guidelines previously approved would permit the Investment Committee to carry out the other recommendations.

17. Rhodes as editor gave a summary of the report to be given at the general business session. He reminded the Board that a new editor is to be named soon. Schuh moved that an ad hoc committee be appointed to solicit, review, and advise the Board at the Winter Meeting on selection of an editor. Seconded. Passed. Schuh and Hopkin were appointed subsequently by Stanton to solicit and receive nominations for review at the December meeting.

18. Rhodes presented a proposed revision of the reprint price schedule as follows:

	No. of Pages			
	1–4	5–8	9–12	13–16
(*a*) First 100 copies current	$31.50	$47.25	$ 56.25	$ 63.00
proposed	60.00	90.00	120.00	150.00
(*b*) Add'l 100 copies current	12.50	19.50	23.75	30.75
proposed	20.00	30.00	40.00	50.00

Those paying page charges would pay the lower rates for any additional copies because they are provided 100 copies at no additional cost while those not paying the page charge must buy the 100 copies first before being eligible to buy additional copies at the lower rate. At present, all purchasers must purchase the first hundred copies. Lane moved that the new schedule be adopted. Seconded. Passed.

19. Rhodes reported that the preparation and publishing of the *AAEA Newsletter* had gone smoothly and expressed confidence that it will become more useful as committees and members learn to use it. Rhodes proposed that the advertising rate in the newsletter be revised from the *Journal* rates of $210 full-page, $115 half-page, $70 quarter-page, and $50 for a short position open ad to the following, which would be more workable:

(*a*) Continue the rate of $50 for employment ads of 85 words or less;

(*b*) For other ads, including those with several positions, the rate be $15 per column inch or fraction thereof, with a $60 minimum and photo-ready full page ads set at $275. The present $50 ad would equal about $12.50 per column inch. There are 19 column inches per page and a full page ad would be

$285 when prepared by the editor. This $275 rate would provide a $10 discount if prepared by the advertiser. Hopkin moved the adoption of the recommended advertising rates. Seconded. Passed.

20. Rhodes reported on criteria for publication outlets for AAEA reports. In 1978, the Board approved the practice of publishing abstracts in the *Newsletter* instead of the full report in the *Journal*. It was recommended that the *Journal* continue to include in full (*a*) the reports of the President, Reso-

would spread the workload of these officers. The significant change from the present practice is to suggest that the president-elect serve as the invited papers program chairman for the summer meeting using the Board as the program committee. The major duties of the person moving through the three positions include:

(*a*) President-Elect: (i) prepare and deliver the presidential address; (ii) serve as invited papers program chairman for summer meeting; (iii) plan

are to sign a form that assigns the authors' and their employers' copyrights to the AAEA. Such a transfer is required for publication, except for manuscripts already in the public domain, such as those of federal employees. Sample suggested statements were provided.

Hildreth moved the report be approved and the steps be implemented. After publication of such notice of the new policy in the *Newsletter* and in the February 1980 issue of the *Journal,* all articles accepted after 1 March 1980 will be subject to the new copyright policy. Seconded. Passed.

26. Stanton presented copies of the final report by the AAEA Committee on Management, Structure, Methods, and Procedures, chaired by Sundquist. It was noted that activities had been put in motion to implement most of the committee recomendations. Further, the committee was not unanimous in its specific recommendation on establishing an executive office for AAEA. Sundquist recommended that this report be presented to the membership for "information only" and that the committee be officially dissolved. Crowder moved that the report be received and the committee be dissolved with thanks. Seconded. Passed.

27. Stovall gave a preliminary report for the ad hoc committee on establishing an office for AAEA. Four alternatives are being explored: (*a*) an office in Washington or Chicago, which would cost an estimated $78,000 more than the secretary-treasurer's office now located in Kentucky (this would amount to about $12 per member and subscriber). (*b*) Contract with another association, such as American Dairy Science Association, to provide business management services including updating of the membership list, handling receipts and disbursements, handling all business and financial aspects of the *Journal,* sending out annual dues notices and receiving and recording dues payments, preparation of income and expense statements, and handling preregistration for annual meetings. For this, the cost is currently $4.50 per member, or about $29,000 per year, and it will likely go to $5 per member. (*c*) Contract the business management function to a consultant. The committee does not have any estimate of cost of such service. (*d*) Continue the secretary-treasurer's office on a part-time basis at a university. It is quite likely that individuals and institutions will be more reluctant than in the past to subsidize the Association in this manner. No action was taken, but a general consensus of the Board was that moving the office to Washington or Chicago was not a viable option. The committee planned to meet again while at Pullman and will report again to the Board in December 1979.

28. Stanton presented a brief preliminary report from Farrell, chairman of the task force on an operational data based for AAEA activities. Initial staff work has been done, which consisted of systematic identification of key decisions made on a recurring basis by the Board and the secretary-treasurer, data required for such decisions, and the availability and location of such data. No decisions were made. The committee planned to meet while at Pullman and expects to have specific proposals for action within twelve months.

29. Padberg reported for the Awards Committee. It was the consensus of the Board that contestants receiving "honorable mention" should receive a letter of congratulations and a copy of the awards program from the chairman of the awards committee.

Lane presented some suggested changes in Article 5, Sections 3 and 4, to identify more clearly in the by-laws that the awards are for outstanding master's thesis and outstanding doctoral thesis and not for programs as such. Lane moved that the by-laws be amended to reflect the changes. Seconded. Passed. These changes will be presented at the end of the Board meeting and published in the updated version of the by-laws.

30. Hildreth reported on the meeting of International Association of Agricultural Economists meeting in Banff, 3–12 September 1979, indicating that ten AAEA members received travel grants from the $2,500 provided by the Association and matched from other IAAE sources.

31. A Report of the Membership Committee, chaired by Mathia, was received. It was noted that Raunikar of Georgia designed and produced a membership brochure and his work was commended. The report provided plans for continuous recruitment of members in individual state locations as well as regionally.

32. Extension Affairs Committee, chaired by Wood, sent a report defining some issues and reflecting the chairman's views regarding the committee and its activities. He requested more definitive direction from the Board for the committee.

33. Schrader reported for the Contributed Papers Committee. Coffey suggested that a more appropriate name be sought for the contributed papers. Because they are screened, they should have more prestige than commonly given them. Coffey moved that the name be changed from "contributed papers" to "selected papers" and to seek methods of publication. Seconded. Motion lost. After continuation of discussion, Lane moved that the name be changed from "contributed papers" to "selected papers." Seconded. Passed.

34. Johnson reported for the Professional Registries and Employment Committee, indicating that 2,480 persons were now listed in the Registry. During the year, the Illinois State Employment Service, where the Registry is located, received 290 job orders and placed 248 persons as compared to 123 a year ealier.

35. Riley reported for the International Committee. It has carried out an AID-funded study entitled "Needs and Strategies for Improving Training of Agricultural Economists for Work in International Agricultural Development." Fienup will present a paper at the IAAE meeting in Banff on the study. Preliminary results have been given at other meet-

ings as well as two symposia at Pullman. Other activities include suggestions to the AAEA Employment Registry Committee on ways to make the registry more useful to prospective employers in the international development area, and a request for arrangements that will expedite AAEA mailings to members residing in foreign countries.

Schuh moved that AAEA express appreciation to the International Committee for a good performance and excellent leadership. Seconded. Passed.

Hildreth moved that if there are no budgetary demands, the AAEA sponsor the publication planned by the International Committee summarizing the AID-funded study. Seconded. Passed.

Schuh moved that the President of AAEA write a letter to AID expressing its support for the type of activity currently done by the Research Training Network (RTN) of the Agricultural Development Council. Seconded. Passed.

36. Rasmussen reported for the Literature Retrieval Committee, indicating that the American Agricultural Economics Documentation Center now provides a range of bibliographic services. A publication is placed in the search system within six weeks after receipt. There has been a marked increase in requests for searches with turn-around time of twenty-four hours for a preliminary search and three days for a comprehensive bibliography.

Rasmussen presented a budget requesting that financial support be increased from $15,000 to $19,000. A question was raised on the extent of use outside the ESCS. The request for increase in funds was delayed until the overall budget is considered.

37. Bromley reported for the Professional Activities Committee which has been concerned with two issues: (*a*) The AAEA sponsorship of conferences, symposial etc. and the criteria for judging the propriety of AAEA sponsorship of various activities. Specific criteria were adopted by the Board at its winter meeting; (*b*) the concern for the future of AAEA which was spawned by the feeling that some important groups of potential members were being missed or that groups of current members were not being served as well as possible. While there was concern voiced about how to meet the needs of groups who viewed themselves as having minority interests, the Committee believed current actions on program and committee membership had helped to meet some of these needs. No action was taken.

38. Stanton presented a request from Charles W. Howe, desiring AAEA and AEA to cosponsor a symposium on the "value of weather information" with the American Meterological Society, with no financial involvement from AAEA. Also, he presented a request from J. L. Butt of the American Society of Agricultural Engineers to cosponsor a National Energy Symposium with no financial involvement.

Schuh moved that the chairman of the Professional Activities Committee and the President designate a person to explore the feasibility of joint sponsorship of a symposium on the value of weather information with the American Meteorological Society and to report to PAC by 1 December 1979 so a recommendation can be made to the Board at the winter meeting. Seconded. Passed.

Lane moved that the previous motion be applied also to the request to cosponsor a National Energy Symposium. Seconded. Passed.

39. O'Connor reported for the Resident Instruction Committee that fifteen papers have been accepted to be presented at the "special undergraduate contributed papers session." A symposium has been planned which has gone to the Professional Activities Committee for evaluation. The AAEA brochure has been approved and turned over to Redman for typesetting, photography, and printing. The by-laws pertaining to student activities are being updated and the Committee will present a revision for Board action in December 1979.

It was the consensus of the Board based on evaluation by the Professional Activities Committee that the idea behind the proposal for the symposium was good but it needed further work before implementation. It was also suggested that the President appoint a person to assist Redman in final preparation of the brochure.

40. Eckert reported on his role as the AAEA liaison person with the American Society of Agronomy and encouraged further interaction on programs.

41. Schuh reported as chairman of the Committee on Nominations for Fellows. The main function of the committee is to provide assistance to the executive board to assure that people deserving to be named as Fellows are considered and nominated. The procedures now followed were outlined. This year, a non-North American was named Fellow for the second time in the history of the Association.

42. Schuh reported as the AAEA representative to the National Bureau of Economic Research. The NBER has made substantial progress in resolving its financial and organizational problems, placing its own program development on a firmer base. Their headquarters were moved from New York to Cambridge, Massachusetts, and their publisher was changed from Ballinger to the University of Chicago Press.

43. Tweeten reported for the Census Advisory Committee on plans underway for the 1982 Census of Agriculture. The committee recommended, in view of budget limitations, that detailed census tabulation be retained and expanded where possible and costs be offset by publishing less detail. The detailed tabulations would be made available through microfilm user tapes, and special reproductions of data on request by users.

44. The Industry Affairs Committee report was circulated. The committee's suggestions for the summer program sessions were so close to what already had been developed, they decided to lend

support and not sponsor separate sessions. The committee is undertaking a project to establish a working list of industry economists and take a survey once the list has been developed to find who they are, what they do, provide a list of speakers and contacts for field trips, determine career path possibilities, and provide information for academic program planning.

45. Gardner reported for the Economic Statistics Committee. He reported on the follow-up activities on the outlook information survey as well as the activities of the task force on productivity measurement issues and on the economic value of statistical information. He discussed the advantages and disadvantages of the invitation for AAEA to participate in a Committee of Professional Associations' on Federal Statistics (COPAFS). It will involve a contribution of $2,000 per year for a period of three years to participate in a three-year pilot program. A staff would be established in Washington which could keep apprised of developments in federal statistics and facilitiate meetings and information exchange among COPAFS members. It was felt that expected changes in federal data systems and statistics in the next few years may affect the quality and usefulness of data pertaining to agriculture and rural society, and COPAFS members are expected to contribute to the improvement of the federal statistical system. The pilot program would get its official go-ahead as of 31 December 1979, if funding is committed to put COPAFS near its $67,500 per year budget goal. The decision to join COPAFS was delayed until the AAEA budget was considered.

46. Martin, as chairman of the Postwar Literature Review Committee, reported on the status of volumes 3 and 4 of the series. He recommended that AAEA authorize negotiations with the University of Minnesota Press on publishing the remaining manuscripts in two separate volumes. He also recommended that AAEA seek financial support from agencies interested in international agriculture for volume 4, which is proposed to consist primarily of a review of economic work in agricultural development in less developed countries.

Lane moved that the literature review publications committee negotiate with the University of Minnesota Press to publish volumes 3 and 4 and be authorized to make and implement the specific decisions involved. Seconded. Passed.

47. Herr reported for the Committee on Non-Land Grant Member Services and endorsed the proposal by the Resident Instruction Committee to sponsor an instructional workshop. He also suggested that this committee be discontinued.

48. Coffey presented a proposed budget.

Hopkin moved that AAEA join COPAFS and contribute $2,000 per year for three years. Seconded. Passed.

Hildreth moved that AAEA discuss the future of the Documentation Center for 1981 and beyond with ESCS, including assessing user charges and evaluation of use of the center. Seconded. Passed. A sum of $17,000 was budgeted.

Coffey moved that a contingency fund of $15,000 be established to cover expected expenses in the future, such as the *Handbook-Directory*. Seconded. Passed. A sum of $8,000 was included in the budget for the publication of volume 4 of the Literature Review.

Other specific adjustments were made which were relatively minor in the proposed budget.

Lane moved the adoption of the 1980 budget with a negative balance of $12,550. Seconded. Passed with one negative vote.

49. Stanton presented a letter discussing research priorities and raised questions about how AAEA should respond in the future to requests for AAEA comments and inputs.

Schuh moved that the Professional Activities Committee be asked to address the question of research priorities with their activities to be divided into two parts: (*a*) a short-term input into the federal budget process and ways to respond to it; (*b*) a longer-term consideration of agricultural economics research, teaching and extension at a variety of levels. Moreover, the outgoing president should participate with the PAC in this effort, and that the PAC in conjunction with the president create a subcommittee to deal with this set of issues. Seconded. Passed.

50. Future meeting sites for 1983 were discussed. Invitations were presented from (*a*) New Orleans, supported by Louisiana State University (*b*) Hot Springs, Arkansas, supported by University of Arkansas; (*c*) Louisville, Kentucky; and (*d*) Purdue University. Hopkin moved that the invitation from Purdue University be accepted. Seconded. Passed.

51. Harl presented a list of amendments to the by-laws required because of the various actions of the Board during the past two days. Hildreth moved the approval of the by-law ammendments and changes in Board policies as follows:

ARTICLE III, Section 1, first sentence amended to read:

> Each member shall pay Association's dues in United States dollars or equivalent for each year from 1 January to 31 December following, payable on or before 1 January of each year in advance.

The following sentences be added at the end of the section:

> Members of the Association and nonmember subscribers to the official *Journal* of the Association shall be charged an additional $2 per year to cover the cost of mailing the *Journal* to locations outside the United States, Canada and Mexico. The Executive Board may from time to time establish surcharges for expedited mailing of other items on an individual or subscription basis.

ARTICLE III, Section 2, the date be changed to 16 January.

ARTICLE V, Section 3, be amended to read as follows:

Outstanding Master's Thesis Award. The Outstanding Master's Thesis awards have as their objective development of professional excellence by individuals writing Master's theses in agricultural, natural resource, or rural economics. Three awards are offered. A cash supplement of $250 accompanies each award.

Nominations may be made from any department in which students write Master's theses in the areas of agricultural, natural resource, or rural economics.

(*a*) An entry must be submitted by the head or chair of the department where the degree is earned.

(*b*) A department may submit one nomination for each fifteen Master's theses or fraction thereof presented to a graduate school faculty in the calendar year preceding the year of recognition. In determining the number of eligible theses departments should limit consideration to theses in the areas of agricultural, natural resource, or rural economics.

(*c*) Nominations should include thesis or other comparable documentation.

(*d*) Selection will be made from documentation approved in final form by the student's advisory committee. The thesis will be eligible for the competition in the calendar year following the one in which the thesis was accepted by the graduate school or division of the degree-granting institution.

(*e*) A published thesis may be entered in both the published research and Master's thesis classes but is eligible for only one award. Although a published thesis is acceptable, a copy of the thesis as submitted to the graduate faculty should be sent whenever possible.

(*f*) Three copies of a thesis (or comparable document) must be sent to the subcommittee chair. All copies are returned after they have been read by the judges.

ARTICLE V, Section 4, be amended to read as follows:

Outstanding Doctoral Thesis Award. The Outstanding Doctoral Thesis awards are given in recognition of development of professional excellence by persons writing doctoral dissertations in agricultural, natural resource, or rural economics. Three awards are given accompanied by a cash supplement of $250 each.

An entry must be submitted by the head or chair of the department where the thesis or comparable document was presented in partial fulfillment of requirements for a degree.

(*a*) A department may submit one nomination for each twelve doctoral theses or fraction thereof presented in agricultural, natural resource, or rural economics to a graduate school faculty in the calendar year preceding the year of recognition. In determining the number of eligible nominations, departments should limit consideration to theses in the areas of agricultural, natural resource, or rural economics.

(*b*) Selection will be made from documentation approved in final form by the student's advisory committee. The thesis will be eligible for the competition in the calendar year following the one in which the thesis was accepted by the graduate school or division of the degree-granting institution.

(*c*) A published thesis may be entered in both the published research and thesis categories but is eligible for only one award. Although a published thesis is acceptable, a copy of the thesis as submitted to the graduate faculty should be sent whenever possible.

(*d*) Three copies of a thesis must be sent to the subcommittee chair. All copies are returned after they have been read by the judges.

Seconded. Passed.

52. Schuh moved that the Board express its appreciation to the outgoing members (Lane, Crowder, and Hildreth). Seconded. Passed.

53. Meeting adjourned 5:30 p.m.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

Minutes of the Annual Business Meeting, Pullman, Washington

The 68th annual meeting was called to order by President B. F. Stanton on 31 July 1979, at 8:30 a.m.

1. Stanton presented for approval the minutes of the annual business meeting held at Blacksburg, Virginia, on 8 August 1978, as published in the "Proceedings" issue of the *Journal*. Motion was duly made to approve the minutes. Seconded. Passed.

2. Stanton announced officially the results of the election of officers. Luther Tweeten was elected president-elect, and Neil Harl and Carleton Dennis were elected as directors.

3. Stanton reviewed and commented on some aspects of AAEA activities during the year. (*a*) Membership has been maintained at a high level for the past two years largely due to not only the activity of the Membership Committee but due to the large number of members being involved in AAEA activities (*b*) The publication of the *AAEA Newsletter* was initiated in 1978. (*c*) The report of the special committee on management structure, methods, and procedures of AAEA activities was completed. (*d*) The Registry of Agricultural Economics is now an established enterprise, operated under a memorandum of agreement with the Illinois State Employment Service. (*e*) The AAEA contributes $17,000 per year, which is about 30% of the cash costs of operating the American Agricultural Economics Documentation Center, a joint enterprise with ESCS. (*f*) The annual meeting program, another major activity of AAEA, is the product of the Executive Board serving as program committee, the President, and President-Elect, who select the symposia, and the committee of seventeen who select the papers for twenty sessions from 213 pa-

pers contributed. And (*g*) the International Committee has been busy carrying out and AID-funded project on "Needs and Strategies for Improving Training of Agricultural Economists for Work in International Agricultural Development." Also, President Stanton (*a*) reminded the members that good work of committees and individuals too often are taken for granted and need member support; (*b*) expressed appreciation for the work of all the committees, especially the Ad Hoc Committee on CAST and the Finance Committee; (*c*) paid tribute to Presidents Nielson, Bonnen, Farrell, and Hildreth, who served during the years on the Board, and who created the wholesome outlook and atmosphere, providing a legacy to all who follow; (*d*) Extended best wishes to Crowder and Lane who leave the Board after three years of excellent service; and (*e*) extended a challenge to all to continue to foster creativity, to maintain the spirit of good will, and to discover new ways for the Association to serve the member needs and interests.

4. Redman presented the Secretary-Treasurer's Report for fiscal year 1 January 1978 through 31 December 1978. Redman also presented a report on AAEA investments for 1978. Motion was made to accept the reports. Seconded. Passed. The reports will be published in the "Proceedings" issue of the *Journal*.

5. Stanton presented the report of the certified public accountant on the financial condition of AAEA and announced that a copy would be on file for anyone desiring to examine it. Motion was made to accept the report. Seconded. Passed.

6. Coffey reported for informational purposes on some budgetary items for 1980, especially the major changes in estimated income and expenses.

7. Rhodes reported as editor of the *Journal*. His report was accepted and will be published in the "Proceedings" issue.

8. Connor reported on the survey conducted to determine if AAEA should join CAST. The recommendation based on the survey was that AAEA should not join CAST as a professional association member. Stanton reported that the Board had voted to accept the recommendation and asked the membership to affirm the action of the Board. Motion was made to accept the recommendation and to affirm the action of the Board. Seconded. Passed.

9. No old business was noted.

10. Tweeten presented a resolution expressing appreciation and gratitude to Washington State University for hosting the meeting. An enthusiastic round of applause expressed approval. The text will be in the "Proceedings" issue.

11. Stanton turned the chair over to Richard King as the Association's new president.

12. Meeting adjourned at 9:30 a.m.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

Index to Volume 61

Subjects

Classification System

Agricultural Economics General; Curricula and Teaching; Extension; Profession

Agricultural Inputs; Capital; Agricultural Finance; Land Appraisal and Prices; Labor; Human Capital

Agricultural Products; Demand, Supply, Prices; Food, Consumer, and Household Economics Arzac, Enrique R., and Maurice Wilkinson.

tion Characteristics on U.S. Consumption of Selected Foods." 1036–45.
Schrimper, R. A. "Demographic Change and the Demand for Food: Discussion." 1058–60.
Selowsky, Marcelo. "Target Group-Oriented Food Programs: Cost Effectiveness Comparisons." 988–94.
Sexauer, Benjamin. "The Effect of Demographic Shifts and Changes in the Income Distribution on Food-Away-from-Home Expenditure." 1046–57.
Taylor, C. Robert, and Hovav Talpaz. "Approximately Optimal Carryover Levels for Wheat in the United States." 32–40.
Timmer, C. Peter, and Harold Alderman. "Estimating Consumption Parameters for Food Policy Analysis." 982–87.

Economic Growth and Development; Planning Models; Fluctuations; Technological Change; Aggregate Production Capacity; Regional and Community; Migration

Bardhan, Pranab K. "Agricultural Development and Land Tenancy in a Peasant Economy: A Theoretical and Empirical Analysis." 48–57.
Cohen, John M., and David B. Lewis. "Capital-Surplus, Labor-Short Economies: Yemen as a Challenge to Rural Development Strategies." 523–28.
Deaton, Brady J. "Rural Employment and Rural-Urban Population Shifts: Discussion." 973–74.
Deere, Carmen Diana, and Alain de Janvry. "A Conceptual Framework for the Empirical Analysis of Peasants." 601–11.
Doran, M. H., A. R. C. Low, and R. L. Kemp. "Cattle as a Store of Wealth in Swaziland: Implications for Livestock Development and Overgrazing in Eastern and Southern Africa." 41–47.
Edwards, Clark. "Modeling Rural Growth." 967–72.
Hoch, Irving. "Settlement Size, Real Income, and the Rural Turnaround." 953–59.
Hyun, K. N., D. W. Adams, and L. J. Hushak. "Rural Household Savings Behavior in South Korea, 1962–76." 448–54.
Knutson, Marlys, and Luther Tweeten. "Toward an Optimal Rate of Growth in Agricultural Production Research and Extension." 70–76.
Nghiep, Le Thanh. "The Structure and Changes of Technology in Prewar Japanese Agriculture." 687–93.
Nguyen, Dũng. "On Agricultural Productivity Differences among Countries." 563–70.
Peterson, Willis L. "International Farm Prices and the Social Cost of Cheap Food Policies." 12–21.
Roumasset, James A. "Sharecropping, Production Externalities, and the Theory of Contracts." 640–47.
Scobie, Grant M. "The Demand for Agricultural Research: A Colombian Illustration." 540–45.
Shaffer, Ron E. "Rural Employment and Rural-Urban Population Shifts: Discussion." 975–76.
Stewart, Fred J., Harry H. Hall, and Eldon D. Smith. "Potential for Increased Income on Small Farms in Appalachian Kentucky." 77–82.

International Economics; Trade; Integration; Business; Aid

Abbott, Philip C. "Modeling International Grain Trade with Government-Controlled Markets." 22–31.
Abbott, Philip C. "The Role of Government Interference in International Commodity Trade Models." 135–40.
Bale, Malcolm D. "A Note on the Distributional Aspects of Price Intervention." 348–50.
Bale, Malcolm D., and Ernst Lutz. "The Effects of Trade Intervention on International Price Instability." 512–16.
Blandford, David, and Seon Lee. "Quantitative Evaluation of Stabilization Policies in International Commodity Markets." 128–34.
Bredahl, Maury E., William H. Meyers, and Keith J. Collins. "The Elasticity of Foreign Demand for U.S. Agricultural Products." 58–63.
Carter, Colin, and Andrew Schmitz. "Import Tariffs and Price Formation in the World Wheat Market." 517–22.
Chambers, Robert G., and Richard E. Just. "A Critique of Exchange Rate Treatment in Agricultural Trade Models." 249–57.
Furtan, W. H., J. G. Nagy, and G. G. Storey. "The Impact on the Canadian Rapeseed Industry from Changes in Transport and Tariff Rates." 238–48.
Griffith, G. R., and Karl D. Meilke. "Relationships among North American Fats and Oils Prices." 335–41.
Hathaway, Dale E. "Changing Patterns of World Trade." 1016–21.
Hayami, Yujiro. "Trade Benefits to All: A Design of Beef Import Liberalization in Japan." 342–47.
Houck, James P. "Agricultural Trade: Protectionism, Policy, and the Tokyo/Geneva Negotiating Round." 860–73.
Johnson, Paul R., Thomas Grennes, and Marie Thursby. "Trade Models with Differentiated Products." 120–27.
Labys, Walter C. "International Commodity Markets and Trade: Discussion." 141–42.
Mayer, Leo V. "Agricultural Trade Issues among Pacific Ocean Countries: Discussion." 1033–35.
McCalla, Alex F., Andrew Schmitz, and Gary G. Storey. "Australia, Canada, and the United States: Trade Partners or Competitors." 1022–29.
McCalla, Alex F., and Andrew Schmitz. "Grain Marketing Systems: The Case of the United States versus Canada." 199–212.
Stern, Robert M. "International Commodity Markets and Trade: Discussion." 143–44.
Thompson, Robert L. "Agricultural Trade Issues among Pacific Ocean Countries: Discussion." 1030–32.
Zwart, A. C., and K. D. Meilke. "The Influence of Domestic Pricing Policies and Buffer Stocks on Price Stability in the World Wheat Industry." 434–47.

Production Economics and Management; Risk and Uncertainty

Public Issues and Policy; Agricultural; Regulations; Taxation; Inflation; Welfare Programs; Poverty; Regional and Community Development; Education; Health

Research Methodology; Modeling; Techniques; Agricultural Data

Authors

Reviews

The reviewers' names are in parentheses.

Editors of the *American Journal of Agricultural Economics*

L. A. Moorhouse	Office of Farm Management, USDA	Vols. 1–3	1919–21
O. C. Stine	Bureau of Agricultural Economics, USDA	4–6	1922–24
E. G. Nourse	Institute of Economics Brookings Institution	7–8	1925–26
H. R. Tolley	Bureau of Agricultural Economics, USDA	9–11	1927–29
H. E. Erdman	University of California-Berkeley	12–14	1930–32
O. B. Jesness	University of Minnesota	15–17	1933–35
H. C. M. Case	University of Illinois	18–19	1936–37
T. W. Schultz	Iowa State University	20–23	1938–41
H. B. Price	University of Kentucky	24–25	1942–43
Warren C. Waite	University of Minnesota	26–30	1944–48
Walter W. Wilcox	Library of Congress	31–33	1949–51
Lawrence W. Witt	Michigan State University	34–36	1952–54
Harold G. Halcrow	University of Connecticut	37–39	1955–57
Robert L. Clodius	University of Wisconsin	40–41	1958–59
Herman M. Southworth	Pennsylvania State University	42–44	1960–62
James Nielson	Michigan State University	45–47	1963–65
Earl R. Swanson	University of Illinois	48–50	1966–68
Varden Fuller	University of California Berkeley (1969) Davis (1970–71)	51–53	1969–71
Leo Polopolus	University of Florida	54–55	1972–73
Max R. Langham and Leo Polopolus, coeditors	University of Florida	55–56	1973–74
William G. Tomek	Cornell University	57–58	1975–76
V. James Rhodes	University of Missouri	60–62	1978–80

American Agricultural Economics Association

President/Richard A. King, North Carolina State University
President-Elect/Luther G. Tweeten, Oklahoma State University
Secretary-Treasurer/John C. Redman, University of Kentucky
Past-President/Bernard F. Stanton, Cornell University

Directors

Thomas G. Brown, University of Missouri
Joseph D. Coffey, Virginia Polytechnic Institute and State University
Carleton C. Dennis, Agway, Inc.
Neil E. Harl, Iowa State University
John A. Hopkin, Texas A&M University
G. Edward Schuh, University of Minnesota

Objective

The AAEA seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy. The activities of the AAEA include:

—publishing the *American Journal of Agricultural Economics;*
—planning and conducting two annual meetings of the membership;
—sponsoring annual awards for outstanding extension programs, distinguished teaching, and outstanding research;
—recognizing outstanding agricultural economists through a fellows program;
—supporting a literature retrieval system in cooperation with the U.S. Department of Agriculture;
—publishing periodically a biographical directory of the AAEA's members;
—supporting an employment registry for agricultural economists in cooperation with the U.S. Department of Labor.

Membership and Subscriptions

Membership in the AAEA is open to individuals having a professional interest in agricultural economics. Dues, payable at the beginning of each calendar year, are as follows: regular members, $25, senior members, $12.50, and junior members, $12.50. Senior membership is open to persons, upon written request, who are sixty-five years of age or older and have retired from active professional work. Junior membership is for students and is limited to three years; students should use application forms available from and signed by the head of the department in which they are studying. Members receive this *Journal.*

Any firm, corporation, association, or partnership may become an institutional member upon payment of $100 per year; institutional members receive three copies of each issue of the *Journal*. Library subscriptions are $35 per year. Individual issues of this *Journal* are $10.00.

Payment of membership dues, correspondence regarding subscriptions, orders for individual copies of the *Journal*, changes in address, or inquiries about the general affairs of the AAEA should be sent to John C. Redman, Secretary-Treasurer, American Agricultural Economics Association, Department of Agricultural Economics, University of Kentucky, Lexington, Kentucky, 40506.